

Department of Aerospace Engineering
and Engineering Mechanics
University of Cincinnati

Proof of Crossplane Symmetry for a Conical Navier-Stokes
Solver

by

Dr. Paul D. Orkwis
Assistant Professor

and

Mr. Raja Sengupta
Research Assistant

19951030 046

September 1995

DPC QUALITY INSPECTED 8

This research was supported by U.S. Army
Research Office Grant # DAAL-03092-G-0240,
Dr. Tom Doligalski, contract monitor, and the
Ohio Supercomputer Center.

REPORT DOCUMENTATION PAGE

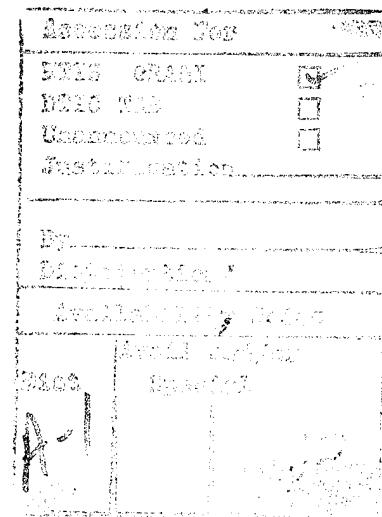
Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)			2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Technical
4. TITLE AND SUBTITLE Proof of Crossplane Symmetry for a Conical Navier-Stokes Solver			5. FUNDING NUMBERS DAAL03-92-G-0240	
6. AUTHOR(S) Mr. Raja Sengupta and Dr. Paul D. Orkwis			8. PERFORMING ORGANIZATION REPORT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Cincinnati Department of Aerospace Engineering and Engineering Mechanics Mail Location 70 Cincinnati, OH 45221-0070			10. SPONSORING / MONITORING AGENCY REPORT NUMBER ARO 29048.3-EG-YIP	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709-2211			12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	
11. SUPPLEMENTARY NOTES The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.				
12b. DISTRIBUTION CODE				
13. ABSTRACT (Maximum 200 words) A formal proof is given for the symmetry of a conical Navier-Stokes solver that has been employed in the computation of vortex asymmetries. The conical Navier-Stokes equations are presented as developed from the generalized coordinate three-dimensional Navier-Stokes equation approach. The solver is then discussed in detail. The proof is first sketched to clarify what must be shown to demonstrate symmetry. The details of the implicit and explicit side symmetry relations are then presented using in part the MACSYMA symbolic manipulation expert system.				
14. SUBJECT TERMS Computational Fluid Dynamics, Conical Navier-Stokes Equations, Vortex Asymmetry, MACSYMA.				15. NUMBER OF PAGES 131
				16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

Abstract

A formal proof is given for the symmetry of a conical Navier-Stokes equation solver that has been employed in the computation of vortex asymmetries. The conical Navier-Stokes equations are presented as developed from the generalized coordinate three-dimensional Navier-Stokes equation approach. The solver is then discussed in detail. The proof is first sketched to clarify what must be shown to demonstrate symmetry. The details of the implicit and explicit side symmetry relations are then presented using in part the MACSYMA symbolic manipulation expert system.



Introduction

This report was prompted by the need to demonstrate symmetry for a conical Navier-Stokes algorithm used in studies of vortex asymmetry about cones at incidence. This issue arises because vortex asymmetry has been observed to occur “naturally” for the conical Navier-Stokes equations (i.e., without external perturbations) whereas it is apparently not observed in similar three-dimensional Navier-Stokes calculations. Vortex asymmetry is found in two of three possible solutions to the nonlinear equation set. These solutions have been found to be stable to perturbations whereas the third (symmetric) solution is thought to be unstable. In fact, the asymmetric solution is found after the solver has converged partially to the symmetric solution. It is felt that roundoff error perturbations excite the instability and redirect the solver to the asymmetric solution. However, it is also conceivable that some algorithm related asymmetries exist which produce the same result, thereby negating any conclusions drawn from solutions obtained by these solvers. It is therefore imperative that the algorithm be symmetric before computational arithmetic is employed.

The following sections report the governing equations that form the basis of this solver, the numerical method used and finally the symmetry proof.

Governing Equations

The conical thin-layer Navier-Stokes equations are obtained from discretizations of the generalized coordinate three-dimensional thin-layer Navier-Stokes equations. A grid is chosen such that the ξ -direction is along rays from the cone tip. Properties are then assumed constant along these rays. In their most general sense the thin-layer Navier-Stokes equations may be written

$$\frac{\partial Q}{\partial \tau} + \frac{\partial F_i}{\partial \xi} + \frac{\partial (G_i - S_v)}{\partial \eta} + \frac{\partial H_i}{\partial \zeta} = 0 \quad (1)$$

where

$$Q = \begin{bmatrix} \rho \\ \rho u \\ \rho v \\ \rho w \\ e \end{bmatrix} \quad F_i = \frac{1}{J} \begin{bmatrix} \rho U \\ \rho uU + \xi_x p \\ \rho vU + \xi_y p \\ \rho wU + \xi_z p \\ (e+p)U \end{bmatrix} \quad G_i = \frac{1}{J} \begin{bmatrix} \rho V \\ \rho uV + \eta_x p \\ \rho vV + \eta_y p \\ \rho wV + \eta_z p \\ (e+p)V \end{bmatrix}$$

$$H_i = \frac{1}{J} \begin{bmatrix} \rho W \\ \rho uW + \zeta_x p \\ \rho vW + \zeta_y p \\ \rho wW + \zeta_z p \\ (e+p)W \end{bmatrix} \quad S_v = \frac{M_\infty \mu}{Re_L J} \begin{bmatrix} 0 \\ \eta_x \sigma_x + \eta_y \tau_{xy} + \eta_z \tau_{xz} \\ \eta_x \tau_{xy} + \eta_y \sigma_y + \eta_z \tau_{yz} \\ \eta_x \tau_{xz} + \eta_y \tau_{yz} + \eta_z \sigma_z \\ \bar{u} S_{v_2} + \bar{v} S_{v_3} + \bar{w} S_{v_4} - \eta_x q_x - \eta_y q_y - \eta_z q_z \end{bmatrix}$$

$$U = \xi_x u + \xi_y v + \xi_z w$$

$$V = \eta_x u + \eta_y v + \eta_z w$$

$$W = \zeta_x u + \zeta_y v + \zeta_z w$$

with \bar{u} , \bar{v} & \bar{w} as average velocities between cells and $\sigma_x, \sigma_y, \sigma_z, \tau_{xy}, \tau_{xz}$ & τ_{yz} having their usual definitions.

A steady form of the above equations is found by neglecting the time derivative of the conserved variables. The resulting equations are solved on a single crossflow (η, ζ) plane grid in which the ξ -direction lines are rays from the cone tip or origin. The conical equations result when constant property boundary conditions are enforced in the radial direction, as described later in the numerical method section. It should be noted that these boundary conditions are necessary only because a three-dimensional solver has been modified to form the conical solver. Boundary conditions are needed only on the surface and far field boundaries for the conical Navier-Stokes equations.

Numerical Method

An implicit upwind symmetric factorization finite volume scheme was employed to solve the above equations. The basic algorithm consists of the implicit or left hand side (LHS) and the explicit or right hand side (RHS) in the form

$$LHS(Q^n) \Delta^n Q = RHS(Q^n) \quad (2)$$

An iteration proceeds from a known Q^n to Q^{n+1} by solving equation (2) for $\Delta^n Q$ and using

$$Q^{n+1} = Q^n + \Delta^n Q$$

RHS

The RHS is differenced using Roe's [Roe] flux difference splitting (FDS) and the Van Albada [VanAl] limiter through Van Leer's [VanLe] MUSCL approach. A convenient way of writing the FDS is presented by Vatsa, Thomas and Wedan [VTW], who detail the contribution of the ξ -direction fluxes as

$$\frac{\partial F}{\partial \xi} = \frac{F_{i+1/2} - F_{i-1/2}}{\Delta \xi}$$

where

$$F_{i+1/2} = \frac{1}{2} [F(Q_L) + F(Q_R) - |\tilde{A}|(Q_R - Q_L)]_{i+1/2}$$

and Q_L and Q_R are functions of neighboring points as described later in the limiter section and $|\tilde{A}|$ is the diagonalized matrix

$$|\tilde{A}| = T|\Lambda|T^{-1}$$

formed from the Roe averaged variables (a function of Q_L and Q_R) with Λ the diagonal eigenvalue matrix, T the matrix of left eigenvectors of A and T^{-1} the matrix of right eigenvectors of A . Note that these matrices are also used for the LHS but in

a slightly different form. The actual matrices can be found in several places including the Vatsa, Thomas and Wedan reference or through the MACSYMA outputs to be presented in a later section.

Flux Limiters

Of interest at this point is how Q_L and Q_R are chosen. In this work Van Leer's [VanLe] MUSCL approach is utilized with the Van Albada [VanAl] flux limiter. The MUSCL approach can be utilized with many limiters, as such, it can be written as

$$Q_L = Q_i + \frac{1}{4} \left\{ (1 - \kappa) \hat{\Delta}_{i-1/2} + (1 + \kappa) \tilde{\Delta}_{i+1/2} \right\}$$

$$Q_R = Q_{i+1} - \frac{1}{4} \left\{ (1 + \kappa) \hat{\Delta}_{i+1/2} + (1 - \kappa) \tilde{\Delta}_{i+3/2} \right\}$$

The Van Albada limiter is obtained by setting $\kappa = 1$

$$Q_L = Q_i + \frac{1}{2} \tilde{\Delta}_{i+1/2}$$

$$Q_R = Q_{i+1} - \frac{1}{2} \hat{\Delta}_{i+1/2} = Q_{i+1} - \frac{1}{2} \tilde{\Delta}_{i+3/2}$$

and

$$\tilde{\Delta}_{i+1/2} = \frac{\Delta_{i-1/2} [\Delta_{i+1/2}^2 + \epsilon] + \Delta_{i+1/2} [\Delta_{i-1/2}^2 + \epsilon]}{\Delta_{i+1/2}^2 + \Delta_{i-1/2}^2 + 2\epsilon}$$

where

$$\Delta_{i+1/2} = Q_{i+1} - Q_i$$

The value of ϵ is typically taken to be a small number to avoid spurious zero divisions.

The above describes how the inviscid terms of the RHS are calculated. The viscous terms are included through central differencing of S_v . This completely describes the algorithm solved via the implicit system. Details of the algorithm can be obtained through the references or by examining the input to MACSYMA for the symmetry checks.

LHS

The LHS can be described by discretizing equation (1) using a simple implicit scheme

$$\frac{\Delta^n Q}{\Delta \tau} + \frac{\partial F_i^{n+1}}{\partial \xi} + \frac{\partial (G_i^{n+1} - S_v^{n+1})}{\partial \eta} + \frac{\partial H_i^{n+1}}{\partial \zeta} = 0 \quad (3)$$

Subtracting the n -level steady terms from both sides and dropping the viscous terms from the LHS gives

$$\begin{aligned} \frac{\Delta^n Q}{\Delta \tau} + \frac{\partial (F_i^{n+1} - F_i^n)}{\partial \xi} + \frac{\partial (G_i^{n+1} - G_i^n)}{\partial \eta} + \frac{\partial (H_i^{n+1} - H_i^n)}{\partial \zeta} \\ = - \left[\frac{\partial F_i^n}{\partial \xi} + \frac{\partial (G_i^n - S_v^n)}{\partial \eta} + \frac{\partial H_i^n}{\partial \zeta} \right] = -RHS^n \end{aligned} \quad (4)$$

and linearizing the inviscid fluxes about the n^{th} level

$$F_i^{n+1} \approx F_i^n + \left. \frac{\partial F_i}{\partial Q} \right|_n \Delta Q^n = F_i^n + A^n \Delta^n Q \quad (5)$$

$$G_i^{n+1} \approx G_i^n + \left. \frac{\partial G_i}{\partial Q} \right|_n \Delta Q^n = G_i^n + B^n \Delta^n Q \quad (6)$$

$$H_i^{n+1} \approx H_i^n + \left. \frac{\partial H_i}{\partial Q} \right|_n \Delta Q^n = H_i^n + C^n \Delta^n Q \quad (7)$$

The above describes how the inviscid terms of the RHS are calculated. The viscous terms are included through central differencing of S_v . This completely describes the algorithm solved via the implicit system. Details of the algorithm can be obtained through the references or by examining the input to MACSYMA for the symmetry checks.

LHS

The LHS can be described by discretizing equation (1) using a simple implicit scheme

$$\frac{\Delta^n Q}{\Delta \tau} + \frac{\partial F_i^{n+1}}{\partial \xi} + \frac{\partial (G_i^{n+1} - S_v^{n+1})}{\partial \eta} + \frac{\partial H_i^{n+1}}{\partial \zeta} = 0 \quad (3)$$

Subtracting the n -level steady terms from both sides and dropping the viscous terms, S_v^{n+1} and S_v^n , from the LHS gives

$$\begin{aligned} \frac{\Delta^n Q}{\Delta \tau} + \frac{\partial (F_i^{n+1} - F_i^n)}{\partial \xi} + \frac{\partial (G_i^{n+1} - G_i^n)}{\partial \eta} + \frac{\partial (H_i^{n+1} - H_i^n)}{\partial \zeta} \\ = - \left[\frac{\partial F_i^n}{\partial \xi} + \frac{\partial (G_i^n - S_v^n)}{\partial \eta} + \frac{\partial H_i^n}{\partial \zeta} \right] = -RHS^n \end{aligned} \quad (4)$$

and linearizing the inviscid fluxes about the n^{th} level

$$F_i^{n+1} \approx F_i^n + \left. \frac{\partial F_i}{\partial Q} \right|_n \Delta Q^n = F_i^n + A^n \Delta^n Q \quad (5)$$

$$G_i^{n+1} \approx G_i^n + \left. \frac{\partial G_i}{\partial Q} \right|_n \Delta Q^n = G_i^n + B^n \Delta^n Q \quad (6)$$

$$H_i^{n+1} \approx H_i^n + \left. \frac{\partial H_i}{\partial Q} \right|_n \Delta Q^n = H_i^n + C^n \Delta^n Q \quad (7)$$

results in

$$\frac{\Delta^n Q}{\Delta \tau} + \frac{\partial}{\partial \xi}(A^n \Delta^n Q) + \frac{\partial}{\partial \eta}(B^n \Delta^n Q) + \frac{\partial}{\partial \zeta}(C^n \Delta^n Q) = -RHS^n$$

or, in operator notation

$$\left[\frac{I}{\Delta \tau} + \left(\frac{\partial A}{\partial \xi} \right)^n + \left(\frac{\partial B}{\partial \eta} \right)^n + \left(\frac{\partial C}{\partial \zeta} \right)^n \right] \Delta^n Q = -RHS^n \quad (8)$$

Finally, multiplying by $\Delta \tau$ gives

$$\left[I + \Delta \tau \left\{ \left(\frac{\partial A}{\partial \xi} \right)^n + \left(\frac{\partial B}{\partial \eta} \right)^n + \left(\frac{\partial C}{\partial \zeta} \right)^n \right\} \right] \Delta^n Q = -\Delta \tau RHS^n \quad (9)$$

where RHS^n is obtained as described above. It is important to note that the scheme is now “semi” implicit since the viscous terms are lagged. However, this does not affect the solution at convergence since it is defined as a zero RHS to machine accuracy. Next the LHS is differenced using the Steger-Warming flux vector splitting (FVS). The scheme can be written

$$\begin{aligned} & \left(I + \Delta \tau \left\{ \nabla_\xi A^+ + \Delta_\xi A^- + \nabla_\eta B^+ + \Delta_\eta B^- + \nabla_\zeta C^+ + \Delta_\zeta C^- \right\} \right) \Delta^n Q \\ &= -\Delta \tau RHS^n \end{aligned} \quad (10)$$

Where A^\pm, B^\pm, C^\pm are the generalized coordinate Steger-Warming [StegWar] FVS Jacobians; $\Delta_\xi, \Delta_\eta, \Delta_\zeta$ are assumed to be unity; and Δ_ξ and ∇_ξ , etc., are the standard two point forward and backward difference operators

$$\begin{aligned} \Delta_\xi(\) &= (\)_{i+1,j,k} - (\)_{i,j,k} \\ \nabla_\xi(\) &= (\)_{i,j,k} - (\)_{i-1,j,k} \end{aligned}$$

It should be noted that the bracketed terms are acting as operators on $\Delta^n Q$ (i.e., $\Delta_\xi A^- \Delta^n Q = [A^- \Delta^n Q]_{i+1,j,k} - [A^- \Delta^n Q]_{i,j,k}$). Details of the Jacobian matrices can be found in the references or can be inferred from the proof. The above produces a block

septa-diagonal system which is not easy to solve. However, the system can be approximately factored so that two block tetra-diagonal systems result

$$\begin{aligned} & \left(I + \Delta\tau \left\{ \nabla_\xi A^+ + \nabla_\eta B^+ + \Delta_\eta B^- \right\} \right) \\ & \quad \left(I + \Delta\tau \left\{ \Delta_\xi A^- + \nabla_\zeta C^+ + \Delta_\zeta C^- \right\} \right) \Delta^n Q = -\Delta\tau RHS^n \end{aligned} \quad (11)$$

This system can then be solved in two steps

$$\left(I + \Delta\tau \left\{ \nabla_\xi A^+ + \nabla_\eta B^+ + \Delta_\eta B^- \right\} \right) Q^* = -\Delta\tau RHS^n \quad (12a)$$

$$\left(I + \Delta\tau \left\{ \Delta_\xi A^- + \nabla_\zeta C^+ + \Delta_\zeta C^- \right\} \right) \Delta^n Q = Q^* \quad (12b)$$

by employing a block tri-diagonal solver while sweeping the ξ -direction in (η, ζ) -planes. For three dimensional problems, forward sweeps are used for equation (12a) and backward sweeps for equation (12b). It is important to note that the above system is symmetric in ζ since both C^+ and C^- are in the same factor. This will become more apparent in the symmetry proof.

The conical solver uses equation (12) in a somewhat abbreviated form. That is, only one plane of cells is considered, therefore,

$$\Delta_\xi A^- \approx -A^-_{i,j,k}$$

$$\nabla_\xi A^- \approx A^-_{i,j,k}$$

This approximation essentially assumes that $\Delta^n Q=0$ for the off plane terms (although they are computed through the conical flow boundary condition.) This term can be removed to improve algorithm efficiency, but has no detrimental effect on the solution. It was retained in the current solver. In any event, it has no bearing on algorithm symmetry as will be shown in the proof.

The conical LHS is as described above and is always solved on a conical grid.

Symmetry Proof

The MACSYMA symbolic manipulation expert system was used to determine the symmetry of the above algorithm. The proof is first sketched in a general sense to provide an overview and then the details are presented.

General Proof

As presented earlier, the conical solver was developed from a generalized coordinate three dimensional solver by simplifying the algorithm when applied on a conical grid. If Cartesian coordinates are used to describe the physical space, the x-direction corresponds to the cone axis; the y-direction is vertical, such that incidence is achieved by a pitch up in the (x,y) plane; and the z-direction is orthogonal to the (x,y) plane. In the computational space the ξ -direction lines are rays from the cone tip and the (η, ζ) plane is perpendicular to the cone axis, with the η -direction normal to the axis and the ζ -direction azimuthal.

For this geometry and grid, symmetry in the crossplane requires that the mirror image grid points (i,j,k) and $(\hat{i},\hat{j},\hat{k})$ at locations (x,y,z) and $(x,y,-z)$, respectively, must have

$$Q_{ijk} = MQ_{\hat{i}\hat{j}\hat{k}}$$

where

$$Q = \begin{bmatrix} \rho \\ \rho u \\ \rho v \\ \rho w \\ e \end{bmatrix} \quad \text{and} \quad M = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Clearly, $M = M^{-1}$.

Furthermore, the metrics are related in the following manner

$$\begin{aligned}
 \left(\frac{\xi_x}{J} \right)_{ijk} &= \left(\frac{\xi_x}{J} \right)_{\hat{i}\hat{j}\hat{k}} \\
 \left(\frac{\xi_y}{J} \right)_{ijk} &= \left(\frac{\xi_y}{J} \right)_{\hat{i}\hat{j}\hat{k}} = 0 \\
 \left(\frac{\xi_z}{J} \right)_{ijk} &= \left(\frac{\xi_z}{J} \right)_{\hat{i}\hat{j}\hat{k}} = 0 \\
 \left(\frac{\eta_x}{J} \right)_{ijk} &= \left(\frac{\eta_x}{J} \right)_{\hat{i}\hat{j}\hat{k}} \\
 \left(\frac{\eta_y}{J} \right)_{ijk} &= \left(\frac{\eta_y}{J} \right)_{\hat{i}\hat{j}\hat{k}} \\
 \left(\frac{\eta_z}{J} \right)_{ijk} &= - \left(\frac{\eta_z}{J} \right)_{\hat{i}\hat{j}\hat{k}} \\
 \left(\frac{\zeta_x}{J} \right)_{ijk} &= - \left(\frac{\zeta_x}{J} \right)_{\hat{i}\hat{j}\hat{k}} \\
 \left(\frac{\zeta_y}{J} \right)_{ijk} &= - \left(\frac{\zeta_y}{J} \right)_{\hat{i}\hat{j}\hat{k}} \\
 \left(\frac{\zeta_z}{J} \right)_{ijk} &= \left(\frac{\zeta_z}{J} \right)_{\hat{i}\hat{j}\hat{k}}
 \end{aligned}$$

Hence, the cell contravariant velocities

$$\begin{aligned}
 U &= \xi_x u + \xi_y v + \xi_z w \\
 V &= \eta_x u + \eta_y v + \eta_z w \\
 W &= \zeta_x u + \zeta_y v + \zeta_z w
 \end{aligned}$$

are related as per

$$U_{i,j,k} = U_{\hat{i},\hat{j},\hat{k}}, \quad V_{i,j,k} = V_{\hat{i},\hat{j},\hat{k}}, \quad W_{i,j,k} = -W_{\hat{i},\hat{j},\hat{k}}$$

To prove symmetry we start with the assumption that the solution from the previous iteration ($n-1$) is symmetric (for $n=1$, this implies the initial condition is symmetric), hence

$$RHS^n_{i,j,k} = M RHS^n_{\hat{i},\hat{j},\hat{k}} \quad (13)$$

Consequently, we expect the intermediate “solution” obtained by solving equation (12a) to be symmetric

$$Q^*_{i,j,k} = M Q^*_{\hat{i},\hat{j},\hat{k}} \quad (14)$$

and hence, the final solution is also symmetric because the change obtained by solving equation (12b) is symmetric

$$\Delta^n Q_{i,j,k} = M \Delta^n Q_{\hat{i},\hat{j},\hat{k}} \quad (15)$$

RHS

Referring to equation (1) it is easy to show that a simple central difference of the RHS is symmetric since

$$\begin{aligned} F_{i,j,k} &= MF_{\hat{i},\hat{j},\hat{k}} \\ G_{i,j,k} &= MG_{\hat{i},\hat{j},\hat{k}} \\ H_{i,j,k} &= -MH_{\hat{i},\hat{j},\hat{k}} \end{aligned}$$

and because the azimuthal ordering prescribes the correspondence $(i,j,k+1)$ to $(\hat{i},\hat{j},\hat{k}-1)$ and $(i,j,k-1)$ to $(\hat{i},\hat{j},\hat{k}+1)$

$$H_{i,j,k\pm 1} = -MH_{\hat{i},\hat{j},\hat{k}\mp 1}$$

therefore,

$$\begin{aligned}\left(\frac{\partial F}{\partial \xi}\right)_{ij,k} &= M \left(\frac{\partial F}{\partial \xi}\right)_{\hat{i}\hat{j}\hat{k}} \\ \left(\frac{\partial G}{\partial \eta}\right)_{ij,k} &= M \left(\frac{\partial G}{\partial \eta}\right)_{\hat{i}\hat{j}\hat{k}} \\ \left(\frac{\partial H}{\partial \zeta}\right)_{ij,k} &= M \left(\frac{\partial H}{\partial \zeta}\right)_{\hat{i}\hat{j}\hat{k}}\end{aligned}$$

This relationship can also be demonstrated for the flux limited Roe FDS discretization, but it is not visually apparent from the equations. It should be noted that the azimuthal ordering oddity significantly complicates the MACSYMA comparison because it requires the identification of the corresponding terms a priori, since the performance of MACSYMA is related to the complexity of the expressions. The MACSYMA derived proof for the RHS requires two steps; demonstrate symmetry for the flux limited variables and then symmetry for the remaining terms. A separate proof is given for each direction as this reduces the MACSYMA workload to a manageable size. These proofs are found in the RHS Proof section following the general proof.

LHS

The LHS expressions also contain the ζ -direction oddity, however, symmetry is easily demonstrated because the following relationships can be proved

$$A^\pm_{ijk} M = M A^\pm_{\hat{i}\hat{j}\hat{k}} \quad (16)$$

$$B^\pm_{ijk} M = M B^\pm_{\hat{i}\hat{j}\hat{k}} \quad (17)$$

$$C^\pm_{ijk} M = -M C^\mp_{\hat{i}\hat{j}\hat{k}} \quad (18)$$

In addition, we have

$$C^\pm_{ijk\pm 1} M = -M C^\mp_{\hat{i}\hat{j}\hat{k}\mp 1} \quad (19)$$

due to the azimuthal direction ordering reversal. These relations will be proven in the LHS Proof section. It should be clear that symmetry cannot be guaranteed in the algorithm unless C^+ and C^- appear in the same factor.

Given the above relationships consider equation (12a) at point (i,j,k) with the operators expanded

$$Q^*_{ijk} + \Delta\tau \left([A^+ Q^*]_{ijk} - [A^+ Q^*]_{i-1jk} + [B^+ Q^*]_{ijk} - [B^+ Q^*]_{i,j-1,k} \right. \\ \left. + [B^- Q^*]_{ij+1,k} - [B^- Q^*]_{ijk} \right) = RHS^n_{ijk} \quad (20)$$

and at the point $(\hat{i},\hat{j},\hat{k})$

$$Q^*_{\hat{ijk}} + \Delta\tau \left([A^+ Q^*]_{\hat{ijk}} - [A^+ Q^*]_{\hat{i}-1,\hat{j},\hat{k}} + [B^+ Q^*]_{\hat{ij},\hat{k}} - [B^+ Q^*]_{\hat{i},\hat{j}-1,\hat{k}} \right. \\ \left. + [B^- Q^*]_{\hat{i}\hat{j}+1,\hat{k}} - [B^- Q^*]_{\hat{ij},\hat{k}} \right) = RHS^n_{\hat{ijk}} \quad (21)$$

Pre-multiply equation (21) by M and use equation (13) to obtain

$$MQ^*_{\hat{ijk}} + \Delta\tau \left([MA^+ Q^*]_{\hat{ijk}} - [MA^+ Q^*]_{\hat{i}-1,\hat{j},\hat{k}} + [MB^+ Q^*]_{\hat{ij},\hat{k}} - [MB^+ Q^*]_{\hat{i},\hat{j}-1,\hat{k}} \right. \\ \left. + [MB^- Q^*]_{\hat{i}\hat{j}+1,\hat{k}} - [MB^- Q^*]_{\hat{ij},\hat{k}} \right) = RHS^n_{ijk} \quad (22)$$

Using relations (16)-(18) in equation (22) gives

$$MQ^*_{\hat{ijk}} + \Delta\tau \left(A^+_{ijk} MQ^*_{\hat{ijk}} - A^+_{i-1jk} MQ^*_{\hat{i}-1,\hat{j},\hat{k}} + B^+_{ijk} MQ^*_{\hat{ij},\hat{k}} \right. \\ \left. - B^+_{ij-1,k} MQ^*_{\hat{i},\hat{j}-1,\hat{k}} + B^-_{ij+1,k} MQ^*_{\hat{i}\hat{j}+1,\hat{k}} - B^-_{ij,k} MQ^*_{\hat{ij},\hat{k}} \right) = RHS^n_{ijk} \quad (23)$$

Subtracting equation (23) from (20) yields

$$[Q^*_{ijk} - MQ^*_{\hat{ijk}}] + \Delta\tau \left(A^+_{ijk} [Q^*_{ijk} - MQ^*_{\hat{ijk}}] - A^+_{i-1jk} [Q^*_{i-1jk} - MQ^*_{\hat{i}-1,\hat{j},\hat{k}}] \right. \\ \left. + B^+_{ijk} [Q^*_{ijk} - MQ^*_{\hat{ij},\hat{k}}] - B^+_{ij-1,k} [Q^*_{ij-1,k} - MQ^*_{\hat{i},\hat{j}-1,\hat{k}}] \right. \\ \left. + B^-_{ij+1,k} [Q^*_{ij+1,k} - MQ^*_{\hat{i}\hat{j}+1,\hat{k}}] - B^-_{ij,k} [Q^*_{ij,k} - MQ^*_{\hat{ij},\hat{k}}] \right) = 0$$

The first, second, fourth and seventh terms within brackets imply equation (14)

$$Q^*_{ijk} = MQ^*_{\hat{ijk}}$$

Similarly, the third term implies

$$Q^*_{i-1,j,k} = MQ^*_{\hat{i}-1,\hat{j},\hat{k}}$$

and the fifth and sixth terms imply

$$Q^*_{i,j\pm 1,k} = MQ^*_{\hat{i}\hat{j}\pm \hat{k}}$$

which, given equations (16)-(18), proves the symmetry of the intermediate step.

Consider next the discretized equation (12b) at the point (i,j,k)

$$\begin{aligned} \Delta^n Q_{i,j,k} + \Delta\tau & \left([A^- \Delta^n Q]_{i+1,j,k} - [A^- \Delta^n Q]_{i,j,k} + [C^+ \Delta^n Q]_{i,j,k} - [C^+ \Delta^n Q]_{i,j,k-1} \right. \\ & \left. + [C^- \Delta^n Q]_{i,j,k+1} - [C^- \Delta^n Q]_{i,j,k} \right) = Q^*_{i,j,k} \end{aligned} \quad (24)$$

and at point $(\hat{i},\hat{j},\hat{k})$

$$\begin{aligned} \Delta^n Q_{\hat{i},\hat{j},\hat{k}} + \Delta\tau & \left([A^- \Delta^n Q]_{\hat{i}+1,\hat{j},\hat{k}} - [A^- \Delta^n Q]_{\hat{i},\hat{j},\hat{k}} + [C^+ \Delta^n Q]_{\hat{i},\hat{j},\hat{k}} - [C^+ \Delta^n Q]_{\hat{i},\hat{j},\hat{k}-1} \right. \\ & \left. + [C^- \Delta^n Q]_{\hat{i},\hat{j},\hat{k}+1} - [C^- \Delta^n Q]_{\hat{i},\hat{j},\hat{k}} \right) = Q^*_{\hat{i},\hat{j},\hat{k}} \end{aligned} \quad (25)$$

Pre-multiply equation (25) by M and use equation (14) to obtain

$$\begin{aligned} M\Delta^n Q_{\hat{i},\hat{j},\hat{k}} + \Delta\tau & \left([MA^- \Delta^n Q]_{\hat{i}+1,\hat{j},\hat{k}} - [MA^- \Delta^n Q]_{\hat{i},\hat{j},\hat{k}} + [MC^+ \Delta^n Q]_{\hat{i},\hat{j},\hat{k}} \right. \\ & \left. - [MC^+ \Delta^n Q]_{\hat{i},\hat{j},\hat{k}-1} + [MC^- \Delta^n Q]_{\hat{i},\hat{j},\hat{k}+1} - [MC^- \Delta^n Q]_{\hat{i},\hat{j},\hat{k}} \right) = Q^*_{i,j,k} \end{aligned} \quad (26)$$

Using relations (16)-(19) in equation (26) gives

$$\begin{aligned} M\Delta^n Q_{\hat{i},\hat{j},\hat{k}} + \Delta\tau & \left(A^-_{i+1,j,k} M\Delta^n Q_{\hat{i}+1,\hat{j},\hat{k}} - A^-_{i,j,k} M\Delta^n Q_{\hat{i},\hat{j},\hat{k}} - C^-_{i,j,k} \Delta^n Q_{\hat{i},\hat{j},\hat{k}} \right. \\ & \left. + C^-_{i,j,k-1} M\Delta^n Q_{\hat{i},\hat{j},\hat{k}-1} - C^+_{i,j,k+1} M\Delta^n Q_{\hat{i},\hat{j},\hat{k}+1} + C^+_{i,j,k} M\Delta^n Q_{\hat{i},\hat{j},\hat{k}} \right) = Q^*_{i,j,k} \end{aligned} \quad (27)$$

Subtracting equation (27) from equation (24) yields

$$\begin{aligned} & [\Delta^n Q_{i,j,k} - M \Delta^n Q_{\hat{i},\hat{j},\hat{k}}] \\ & + \Delta \tau \left(A^-_{i+1,j,k} [\Delta^n Q_{i+1,j,k} - M \Delta^n Q_{\hat{i}+1,\hat{j},\hat{k}}] - A^-_{i,j,k} [\Delta^n Q_{i,j,k} - M \Delta^n Q_{\hat{i},\hat{j},\hat{k}}] \right. \\ & - C^-_{i,j,k} [\Delta^n Q_{i,j,k} - M \Delta^n Q_{\hat{i},\hat{j},\hat{k}}] + C^-_{i,j,k+1} [\Delta^n Q_{i,j,k+1} - M \Delta^n Q_{\hat{i},\hat{j},\hat{k}-1}] \\ & \left. - C^+_{i,j,k-1} [\Delta^n Q_{i,j,k-1} - M \Delta^n Q_{\hat{i},\hat{j},\hat{k}+1}] + C^+_{i,j,k} [\Delta^n Q_{i,j,k} - M \Delta^n Q_{\hat{i},\hat{j},\hat{k}}] \right) = 0 \end{aligned} \quad (28)$$

The first, third, fourth and seventh terms within brackets imply equation (15)

$$\Delta^n Q_{i,j,k} = M \Delta^n Q_{\hat{i},\hat{j},\hat{k}}$$

Similarly, the second term implies

$$\Delta^n Q_{i+1,j,k} = M \Delta^n Q_{\hat{i}+1,\hat{j},\hat{k}}$$

and the fifth and sixth terms imply

$$\Delta^n Q_{i,j,k\pm 1} = M \Delta^n Q_{\hat{i},\hat{j},\hat{k}\mp 1}$$

which is what needs to be proved. Using logic similar to that above this property holds for all (i, j, k) in the linear system and the algorithm is found to be symmetric.

RHS Proof

Proof of symmetry for the RHS requires that equation (13) be demonstrated. The RHS discretization is detailed in the Numerical Method section as it is applied to the steady form of equation (1). It is quite clear from that discussion that the discretization is rather complicated, therefore, the symmetry of the flux terms for each direction are demonstrated separately. The ξ -direction term is relatively straightforward and requires no additional manipulation, however, the η and ζ -direction terms are much more involved and the MACSYMA system was utilized.

ξ -Direction

Recall that the ξ -direction flux term may be written

$$\frac{\partial F_i}{\partial \xi} = \frac{F_{i+1/2} - F_{i-1/2}}{\Delta \xi}$$

where

$$F_{i+1/2} = \frac{1}{2} [F(Q_R) + F(Q_L) - |\tilde{A}|(Q_R - Q_L)]_{i+1/2}$$

The conical Navier-Stokes solver employs a conical grid and the assumption that properties are constant in the ξ -direction. Therefore, $Q_R - Q_L = 0$ and the scheme reverts to simple central difference in this direction. However, it is important to recognize that the flux contribution is not zero since $F(Q_R) \neq F(Q_L)$ due to the grid. In addition, for the conical grid, equation (1) gives

$$F_i = \frac{1}{J} \begin{bmatrix} \rho U \\ \rho u U + \xi_x p \\ \rho v U \\ \rho w U \\ (e + p)U \end{bmatrix}$$

In which only w has opposite sign when comparing points (i,j,k) and $(\hat{i},\hat{j},\hat{k})$.

It is therefore easy to see that

$$F_{ijk} = MF_{\hat{i}\hat{j}\hat{k}} \quad (29)$$

Hence,

$$\left(\frac{\partial F_i}{\partial \xi} \right)_{ijk} = M \left(\frac{\partial F_i}{\partial \xi} \right)_{\hat{i}\hat{j}\hat{k}}$$

η -Direction

Unfortunately, it is not as easy to demonstrate symmetry for the η -direction. In this case we must show that

$$\left(\frac{\partial (G_i - S_v)}{\partial \eta} \right)_{ijk} = M \left(\frac{\partial (G_i - S_v)}{\partial \eta} \right)_{\hat{i}\hat{j}\hat{k}}$$

Recall that

$$\left(\frac{\partial G_i}{\partial \eta} \right)_{ijk} = \frac{G_{ij+1/2,k} - G_{ij-1/2,k}}{\Delta \eta}$$

and

$$G_{ij+1/2,k} = \frac{1}{2} [G(Q_R) + G(Q_L) - |\tilde{B}|(Q_R - Q_L)] \quad (30)$$

Then since $G_{ij-1/2,k}$ is defined in a similar manner it is sufficient to show that

$$G_{ij+1/2,k} = MG_{\hat{i}\hat{j}+1/2,\hat{k}} \quad (31)$$

and since central differences are used for the viscous terms

$$S_{v_{i,j,k}} = MS_{v_{\hat{i},\hat{j},\hat{k}}} \quad (32)$$

The MACSYMA symbolic manipulation system was utilized to demonstrate these relations. However, even in this simplified form MACSYMA requires further simplification. This can be accomplished by first demonstrating

$$\begin{aligned} Q_{R_{ij+1/2,k}} &= M Q_{R_{\hat{i}\hat{j}+1/2,\hat{k}}} \\ Q_{L_{ij+1/2,k}} &= M Q_{L_{\hat{i}\hat{j}+1/2,\hat{k}}} \end{aligned} \quad (33)$$

and then using these results to prove equation (30). The proof is therefore separated into a proof of equation (33), followed by a proof of equation (31) and finally a proof of equation (32). These proofs are accomplished respectively through the MACSYMA scripts Gflux1.max, Gflux2.mac and Gflux3.mac whose recorded inputs and results are found in files Gflux1, Gflux2 and Gflux3 in Appendix A. Note that all of the MACSYMA routines are included in the appendix for clarity. In addition, all demonstrate a zero difference between the selected terms, therefore, symmetry is proved when a null vector or matrix results. The routines themselves were written based on the actual code using identical variable names. Because of this, a few variable names are used several times. The code variables are identified with the notation discussed earlier in the Numerical Method section. It should be clear that the proofs for each direction are sequential, therefore, the results from the first in a series are used in the following series.

Gflux1 proves that given

$$\begin{aligned} dq_{ij,k} &= \Delta_{i,j+1/2,k} = Q_{ij+1,k} - Q_{ij,k} = M(Q_{\hat{i}\hat{j}+1,\hat{k}} - Q_{\hat{i}\hat{j}\hat{k}}) = M\Delta_{\hat{i}\hat{j}+1/2,\hat{k}} = M dq_{\hat{i}\hat{j}\hat{k}} \\ dqm1_{ij,k} &= \Delta_{i,j-1/2,k} = Q_{ij,k} - Q_{ij-1,k} = M(Q_{\hat{i}\hat{j},\hat{k}} - Q_{\hat{i}\hat{j}-1,\hat{k}}) = M\Delta_{\hat{i}\hat{j}-1/2,\hat{k}} = M dqm1_{\hat{i}\hat{j}\hat{k}} \\ dqp1_{ij,k} &= \Delta_{i,j+3/2,k} = Q_{ij+2,k} - Q_{ij+1,k} = M(Q_{\hat{i}\hat{j}+2,\hat{k}} - Q_{\hat{i}\hat{j}+1,\hat{k}}) = M\Delta_{\hat{i}\hat{j}+3/2,\hat{k}} = M dqp1_{\hat{i}\hat{j},\hat{k}} \\ qp_{ij,k} &= Q_{R_{ij+1/2,k}} = Q_{ij+1,k} = M Q_{\hat{i}\hat{j}+1,\hat{k}} = M Q_{R_{\hat{i}\hat{j}+1/2,\hat{k}}} = M qp_{\hat{i}\hat{j}\hat{k}} \\ qm_{ij,k} &= Q_{L_{ij+1/2,k}} = Q_{ij,k} = M Q_{\hat{i}\hat{j},\hat{k}} = M Q_{L_{\hat{i}\hat{j}+1/2,\hat{k}}} = M qm_{\hat{i}\hat{j},\hat{k}} \end{aligned}$$

the following holds

$$\begin{aligned} sp1_{ij,k} &= \hat{\Delta}_{ij+1/2,k} = M\hat{\Delta}_{\hat{i}\hat{j}+1/2,\hat{k}} = Msp2_{ij,\hat{k}} \\ sm1_{ij,k} &= \tilde{\Delta}_{ij+1/2,k} = M\tilde{\Delta}_{\hat{i}\hat{j}+1/2,\hat{k}} = Msm2_{ij,\hat{k}} \end{aligned}$$

Note that the variables qp , qm and dq are then overwritten in the code to form higher order expressions for Q_R and Q_L using

$$\begin{aligned} qp_{ij,k} &= Q_{ij+1,k} - \frac{1}{2}sp1_{ij,k} = Q_{R_{ij+1/2,k}} \\ &= M(Q_{\hat{i}\hat{j}+1,\hat{k}} - \frac{1}{2}sp2_{ij,\hat{k}}) = MQ_{R_{\hat{i}\hat{j}+1/2,\hat{k}}} \\ qp_{ij,k} &= Mqp_{ij,\hat{k}} \end{aligned} \quad (34)$$

and

$$\begin{aligned} qm_{ij,k} &= Q_{ij,k} + \frac{1}{2}sm1_{ij,k} = Q_{L_{ij+1/2,k}} \\ &= M(Q_{ij,\hat{k}} + \frac{1}{2}sm2_{ij,\hat{k}}) = MQ_{L_{ij+1/2,\hat{k}}} \\ qm_{ij,k} &= Mqm_{ij,\hat{k}} \end{aligned} \quad (35)$$

So that the symmetry relation for $dq = Q_R - Q_L$ is given by

$$\begin{aligned} dq_{ij,k} &= qp_{ij,k} - qm_{ij,k} \\ &= M(qp_{ij,\hat{k}} - qm_{ij,\hat{k}}) \\ &= Mdq_{ij,\hat{k}} \end{aligned} \quad (36)$$

Equations (34)-(36) are then used in Gflux2 to prove equation (31). Gflux3 completes the η -direction demonstrations by proving equation (32) using the variable gs in place of S_v .

ζ -Direction

The last direction is the most difficult because of the azimuthal ordering. It is easy to see that

$$\begin{aligned} k-2 &\leftrightarrow \hat{k}+2 \\ k-1 &\leftrightarrow \hat{k}+1 \\ k &\leftrightarrow \hat{k} \\ k+1 &\leftrightarrow \hat{k}-1 \\ k+2 &\leftrightarrow \hat{k}-2 \end{aligned}$$

Once again, the desired symmetry property is

$$\left(\frac{\partial H_i}{\partial \zeta} \right)_{ij,k} = M \left(\frac{\partial H_i}{\partial \zeta} \right)_{\hat{i},\hat{j},\hat{k}}$$

where

$$\left(\frac{\partial H_i}{\partial \zeta} \right)_{ij,k} = \frac{H_{ijk+1/2} - H_{ijk-1/2}}{\Delta \zeta}$$

and Roe's FDS gives

$$H_{ijk+1/2} = \frac{1}{2} [H(Q_R) + H(Q_L) - |\tilde{C}|(Q_R - Q_L)]_{ijk+1/2} \quad (37)$$

Therefore, the symmetry relation that must be proved is

$$H_{ijk+1/2} = -M H_{\hat{i},\hat{j},\hat{k}-1/2} \quad (38)$$

Once again, the first proof, Hflux1, shows that given

$$\begin{aligned}
 dq_{ij,k} &= \Delta_{ij,k+1/2} = Q_{ij,k+1} - Q_{ij,k} = M(Q_{\hat{i}\hat{j}\hat{k}-1} - Q_{\hat{i}\hat{j}\hat{k}}) = -M\Delta_{\hat{i}\hat{j}\hat{k}-1/2} = -Mdq_{\hat{i}\hat{j}\hat{k}-1} \\
 dqpI_{ij,k} &= \Delta_{ij,k+3/2} = Q_{ij,k+2} - Q_{ij,k+1} = M(Q_{\hat{i}\hat{j}\hat{k}-2} - Q_{\hat{i}\hat{j}\hat{k}-1}) = -M\Delta_{\hat{i}\hat{j}\hat{k}-3/2} = -MdqmI_{\hat{i}\hat{j}\hat{k}-1} \\
 dqmI_{ij,k} &= \Delta_{ij,k-1/2} = Q_{ij,k} - Q_{ij,k-1} = M(Q_{\hat{i}\hat{j}\hat{k}} - Q_{\hat{i}\hat{j}\hat{k}+1}) = -M\Delta_{\hat{i}\hat{j}\hat{k}+1/2} = -MdqpI_{\hat{i}\hat{j}\hat{k}-1} \\
 qp_{ij,k} &= Q_{ij,k+1} = MQ_{\hat{i}\hat{j}\hat{k}-1} = Mqm_{\hat{i}\hat{j}\hat{k}-1} \\
 qm_{ij,k} &= Q_{ij,k} = MQ_{\hat{i}\hat{j}\hat{k}} = Mqp_{\hat{i}\hat{j}\hat{k}-1}
 \end{aligned}$$

the following holds

$$\begin{aligned}
 sp1_{ij,k} &= \hat{\Delta}_{ij,k+1/2} = -M\hat{\Delta}_{\hat{i}\hat{j},\hat{k}-1/2} = -Msm2_{\hat{i}\hat{j},\hat{k}-1} \\
 sm1_{ij,k} &= \tilde{\Delta}_{ij,k+1/2} = -M\tilde{\Delta}_{\hat{i}\hat{j},\hat{k}-1/2} = -Msp2_{\hat{i}\hat{j},\hat{k}-1}
 \end{aligned}$$

Then since

$$\begin{aligned}
 qp_{ij,k} &= Q_{ij,k+1} - \frac{1}{2}sp1_{ij,k} = Q_{R_{ij,k+1/2}} \\
 &= M(Q_{\hat{i}\hat{j}\hat{k}-1} + \frac{1}{2}sm2_{\hat{i}\hat{j},\hat{k}-1}) = MQ_{L_{\hat{i}\hat{j},\hat{k}-1/2}} \\
 qp_{ij,k} &= Mqm_{\hat{i}\hat{j},\hat{k}-1} \tag{39}
 \end{aligned}$$

similarly

$$\begin{aligned}
 qm_{ij,k} &= Q_{ij,k} + \frac{1}{2}sm1_{ij,k} \\
 &= M(Q_{\hat{i}\hat{j}\hat{k}} - \frac{1}{2}sp2_{\hat{i}\hat{j},\hat{k}-1}) \\
 qm_{ij,k} &= Mqp_{\hat{i}\hat{j},\hat{k}-1} \tag{40}
 \end{aligned}$$

So the symmetry relation for $dq = Q_R - Q_L$ is given by

$$\begin{aligned} dq_{i,j,k} &= qp_{ij,k} - qm_{i,j,k} \\ &= M(qm_{\hat{i}\hat{j}\hat{k}-1} - qp_{\hat{i}\hat{j}\hat{k}-1}) \\ &= -Mdq_{\hat{i}\hat{j}\hat{k}-1} \end{aligned} \quad (41)$$

Equations (39)-(41) are then used in Hflux2 to prove equation (38).

Equations (29), (31), (32) and (38) collectively prove equation (13) and symmetry is demonstrated from the RHS.

LHS Proof

The LHS proof is somewhat simpler to describe because a major portion of it has been presented in the General Proof section. Equations (16) - (18) must be proved to demonstrate the symmetry of the LHS. IN addition, the expressions to be evaluated are considerably more complicated than their RHS counterparts. Because of this the eigenvalues were included in a less general form (i.e., without absolute values) for specific sub- and supersonic cases.

Again the MACSYMA symbolic manipulation routine was used and the resulting scripts are included in Appendix A. The files have the following naming convention

$A^+_{ijk} M = MA^+_{\hat{i}, \hat{j}, \hat{k}}$	- apsup	- supersonic
	- apsub	- subsonic
$A^-_{ijk} M = MA^-_{\hat{i}, \hat{j}, \hat{k}}$	- amsup	- supersonic
	- amsub	- subsonic
$B^+_{ijk} M = MB^+_{\hat{i}, \hat{j}, \hat{k}}$	- bpsup	- supersonic
	- bpsub	- subsonic
$B^-_{ijk} M = MB^-_{\hat{i}, \hat{j}, \hat{k}}$	- bmsup	- supersonic
	- bmsub	- subsonic
$C^+_{ijk} M = -MC^-_{\hat{i}, \hat{j}, \hat{k}}$	- ccsup1	- supersonic
	- ccsub1	- subsonic

Note that only one set of identities must be shown for the ζ -direction since the inverse is included in those presented. It should be recognized that sub- and supersonic flows can occur in both the plus and minus coordinate directions. These cases were tested and identical results were obtained. They were deleted from the current report to save space. The interested reader can verify the proof by simple alterations to the MACSYMA scripts included in the appendix.

Given the above proofs the symmetry properties of the LHS are established and hence the algorithm is shown to be symmetric for conical grids.

Summary

The symmetry of a conical Navier-Stokes equation solver was proved through the use of analytical and symbolic techniques. The MACSYMA symbolic manipulation software was utilized. MACSYMA routines are included to allow the interested reader to verify the results.

References

- [Roe] P.L. Roe, Approximate Riemann Solvers, Parameter Vectors, and Difference Schemes, *Journal of Computational Physics*, **43**, 357, (1981).
- [VanAl] G.D. van Albada, B. van Leer and W.W. Roberts, A Comparative Study of Computational Methods in Cosmic Gas Dynamics, *Astronomy and Astrophysics*, **108**, 76, (1982).
- [VanLe] B. van Leer, Towards the Ultimate Conservative Difference Scheme V: A Second Order Sequel to Godunov's Methods, *Journal of Computational Physics*, **32**, 101, (1979).
- [VTW] V.N. Vatsa, J.L. Thomas and B.W. Wedan, Navier-Stokes Computations of a Prolate Spheroid at Angle of Attack, *Journal of Aircraft*, **26**, 1002, (1989).
- [StegWar] J.L. Steger and R.F. Warming, Flux Vector Splitting of the Gasdynamic Equations with Application to Finite-Difference Methods, *Journal of Computational Physics*, **40**, 263, (1981).
- [Mac] Macsyma Reference Manual Version 13, Symbolics (1988).

Appendix A

- GFLUX1
- GFLUX2
- GFLUX3
- HFLUX1
- HFLUX2
- APSUP
- APSUB
- AMSUP
- AMSUB
- BPSUP
- BPSUB
- BMSUP
- BMSUB
- CCSUP1
- CCSUB1

```

(C3) diff:matrix([0],[0],[0],[0],[0])$
(C4) g:matrix([0],[0],[0],[0],[0])$
(C5) gijk:matrix([0],[0],[0],[0],[0])$
(C6) ghatijk:matrix([0],[0],[0],[0],[0])$
(C7) sp:matrix([0],[0],[0],[0],[0])$
(C8) null:matrix([0],[0],[0],[0],[0])$
(C9) xy2:matrix([0],[0],[0],[0],[0])$
(C10) x2y:matrix([0],[0],[0],[0],[0])$
(C11) xpy:matrix([0],[0],[0],[0],[0])$
(C12) sp1:matrix([0],[0],[0],[0],[0])$
(C13) sp2:matrix([0],[0],[0],[0],[0])$
(C14) sm1:matrix([0],[0],[0],[0],[0])$
(C15) sm2:matrix([0],[0],[0],[0],[0])$
(C16) ax:etx$ 
(C17) ay:ety$ 
(C18) az:etz$ 
(C19) dq:matrix([rp1-r],[rup1-ru],[rvp1-rv],[rwp1-rw],[ep1-e],[pp1-p])$ 
(C20) dqm1:matrix([r-rm1],[ru-rum1],[rv-rvm1],[rw-rwm1],[e-em1],[p-pm1])$ 
(C21) dqp1:matrix([rp2-rp1],[rup2-rup1],[rvp2-rvp1],[rwp2-rwp1],[e p2-ep1],[pp2-pp1])$ 
(C22) qp:matrix([rp1],[rup1],[rvp1],[rwp1],[ep1],[pp1])$ 
(C23) qm:matrix([r],[ru],[rv],[rw],[e],[p])$ 
(C24) for i: 1 thru 6 do
xy2[i]:= dqm1[i]*(dq[i]*dq[i]+eps)$ 
(C25) for i:1 thru 6 do
x2y[i]:= dq[i]*(dqm1[i]*dqm1[i]+eps)$ 
(C26) for i:1 thru 6 do
xpy[i]:= dqm1[i]*dqm1[i] + dq[i]*dq[i]$ 
(C27) for i:1 thru 6 do
sm1[i]:=(x2y[i]+xy2[i])/(xpy[i]+2*eps)$ 
(C28) for i: 1 thru 6 do
xy2[i]:= dqp1[i]*(dq[i]*dq[i]+eps)$ 
(C29) for i:1 thru 6 do
x2y[i]:= dq[i]*(dqp1[i]*dqp1[i]+eps)$ 
(C30) for i:1 thru 6 do
xpy[i]:= dqp1[i]*dqp1[i] + dq[i]*dq[i]$ 
(C31) for i:1 thru 6 do
sp1[i]:=(x2y[i]+xy2[i])/(xpy[i]+2*eps)$ 
(C32) m:matrix([1,0,0,0,0,0],[0,1,0,0,0,0],[0,0,1,0,0,0],[0,0,0,-1,0,0],[0,0,0,0,1,0],[0,0,0,0,0,1])$ 
(C33) ax:etx$ 
(C34) ay:ety$ 
(C35) az:-etz$ 
(C36) dq:m.dq$ 
(C37) dqm1:m.dqm1$ 
(C38) dqp1:m.dqp1$ 
(C39) qp:m.qp$ 
(C40) qm:m.qm$ 

```

```

(C41) for i: 1 thru 6 do
xy2[i]:= dqm1[i]*(dq[i]*dq[i]+eps)$
(C42) for i:1 thru 6 do
x2y[i]:= dq[i]:(dqm1[i]*dqm1[i]+eps)$
(C43) for i:1 thru 6 do
xpy[i]:= dqm1[i]*dqm1[i] + dq[i]*dq[i]$ 
(C44) for i:1 thru 6 do
sm2[i]:=(x2y[i]+xy2[i])/(xpy[i]+2*eps)$
(C45) for i: 1 thru 6 do
xy2[i]:= dqp1[i]*(dq[i]*dq[i]+eps)$
(C46) for i:1 thru 6 do
x2y[i]:= dq[i]:(dqp1[i]*dqp1[i]+eps)$
(C47) for i:1 thru 6 do
xpy[i]:= dqp1[i]*dqp1[i] + dq[i]*dq[i]$ 
(C48) for i:1 thru 6 do
sp2[i]:=(x2y[i]+xy2[i])/(xpy[i]+2*eps)$
(C49) diff1:=sp1-m.sp2$
(C50) diff1:=ratexpand(diff1);

```

(D50)

$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

(C51) diff2:=sm1-m.sm2\$

(C52) diff2:=ratexpand(diff2);

(D52)

$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

(C53) closefile(gflux1)\$

```

(C3) diff:matrix([0],[0],[0],[0],[0])$
(C4) g:matrix([0],[0],[0],[0],[0])$
(C5) gijk:matrix([0],[0],[0],[0],[0])$
(C6) ghatijk:matrix([0],[0],[0],[0],[0])$
(C7) sp:matrix([0],[0],[0],[0],[0])$
(C8) dq:matrix([0],[0],[0],[0],[0])$
(C9) null:matrix([0],[0],[0],[0],[0],[0])$
(C10) xy2:matrix([0],[0],[0],[0],[0],[0])$
(C11) x2y:matrix([0],[0],[0],[0],[0],[0])$
(C12) xpy:matrix([0],[0],[0],[0],[0],[0])$
(C13) sp1:matrix([0],[0],[0],[0],[0])$
(C14) sp2:matrix([0],[0],[0],[0],[0])$
(C15) sm1:matrix([0],[0],[0],[0],[0])$
(C16) sm2:matrix([0],[0],[0],[0],[0])$
(C17) ax:etx$
(C18) ay:ety$
(C19) az:etz$
(C20) axt:ax/sada$
(C21) ayt:ay/sada$
(C22) azt:az/sada$
(C23) dq:matrix([dq1],[dq2],[dq3],[dq4],[dq5])$
(C24) qp:matrix([qp1],[qp2],[qp3],[qp4],[qp5],[qp6])$
(C25) qm:matrix([qm1],[qm2],[qm3],[qm4],[qm5],[qm6])$
(C26) axt:ax/sada$
(C27) ayt:ay/sada$
(C28) azt:az/sada$
(C29) e1:tt*sada$
(C30) e4:e1+csad$
(C31) e5:e1-csad$
(C32) be1:matrix([0.5*(e1+abs(e1)),0,0,0,0],
[0,0.5*(e1+abs(e1)),0,0,0],
[0,0,0.5*(e1+abs(e1)),0,0],
[0,0,0,0.5*(e4+abs(e4)),0],
[0,0,0,0,0.5*(e5+abs(e5))])$
(C33) be2:matrix([0.5*(e1-abs(e1)),0,0,0,0],
[0,0.5*(e1-abs(e1)),0,0,0],
[0,0,0.5*(e1-abs(e1)),0,0],
[0,0,0,0.5*(e4-abs(e4)),0],
[0,0,0,0,0.5*(e5-abs(e5))])$
(C34) a:q1/(sqrt(2)*c)$
(C35) c1:0.5*rqrq$
(C36) c2:c*c/gm1$
(C37) br:matrix([axt,ayt,azt,a,a],
[q2*axt,q2*ayt-q1*azt,q2*azt+q1*ayt,a*(q2+c*axt),a*(q2-c*axt)],
[q3*axt+q1*azt,q3*ayt,q3*azt-q1*axt,a*(q3+c*ayt),a*(q3-c*ayt)],
[q4*axt-q1*ayt,q4*ayt+q1*axt,q4*azt,a*(q4+c*azt),a*(q4-c*azt)],
[c1*axt+q1*(q3*azt-q4*ayt),c1*ayt+q1*(q4*axt-q2*azt),
c1*azt+q1*(q2*ayt-q3*axt),a*(c1+c2+c*tt),a*(c1+c2-c*tt)])$
(C38) phi:0.5*gm1*rqrq$
(C39) c2:c*c$
(C40) b:1/(sqrt(2)*rc)$

```

```

(C41) c1:1-phi/c2$
(C42) c3:gml/c2$
(C43) bl:matrix([axt*c1+q6*(q4*ayt-q3*azt), axt*q2*c3, axt*q3*c3+azt
*q6,
axt*q4*c3-ayt*q6,-axt*c3],
[ayt*c1+q6*(q2*azt-q4*axt), ayt*q2*c3-azt*q6, ayt*q3*c3,
ayt*q4*c3+axt*q6,-ayt*c3],
[azt*c1+q6*(q3*axt-q2*ayt), azt*q2*c3+ayt*q6, azt*q3*c3-axt*q6,
azt*q4*c3,-azt*c3],
[b*(phi-c*tt), b*(c*axt-q2*gml), b*(c*azt-q4*gml),
b*gml],
[b*(phi+c*tt), -b*(c*axt+q2*gml), -b*(c*ayt+q3*gml), -b*(c*azt+q4*gml
),
b*gml])$ 
(C44) sp:bl.dq$ 
(C45) sp2:be1.sp$ 
(C46) sp:bl.dq$ 
(C47) sm2:be2.sp$ 
(C48) g:br.sm2-br.sp2$ 
(C49) tl:(qm[2]*ax+qm[3]*ay+qm[4]*az)/qm[1]$ 
(C50) g[1]:qm[1]*tl+g[1]$ 
(C51) g[2]:qm[2]*tl+ax*qm[6]+g[2]$ 
(C52) g[3]:qm[3]*tl+ay*qm[6]+g[3]$ 
(C53) g[4]:qm[4]*tl+az*qm[6]+g[4]$ 
(C54) g[5]: (qm[5]+qm[6])*tl+g[5]$ 
(C55) tl:(qp[2]*ax+qp[3]*ay+qp[4]*az)/qp[1]$ 
(C56) gijk[1]:0.5*(qp[1]*tl+g[1])$ 
(C57) gijk[2]:0.5*(qp[2]*tl+ax*qp[6]+g[2])$ 
(C58) gijk[3]:0.5*(qp[3]*tl+ay*qp[6]+g[3])$ 
(C59) gijk[4]:0.5*(qp[4]*tl+az*qp[6]+g[4])$ 
(C60) gijk[5]:0.5*((qp[5]+qp[6])*tl+g[5])$ 
(C61) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0
,0,0,0,1])$ 
(C62) m2:matrix([1,0,0,0,0,0],[0,1,0,0,0,0],[0,0,1,0,0,0],[0,0,0,-
1,0,0],
[0,0,0,0,1,0],[0,0,0,0,0,1])$ 
(C63) ax:etx$ 
(C64) ay:ety$ 
(C65) az:-etz$ 
(C66) axt:ax/sada$ 
(C67) ayt:ay/sada$ 
(C68) azt:az/sada$ 
(C69) rw:-rw$ 
(C70) rwp1:-rwp1$ 
(C71) rwp2:-rwp2$ 
(C72) rwm1:-rwm1$ 
(C73) dq:m.dq$ 
(C74) qp:m2.qp$ 
(C75) qm:m2.qm$ 
(C76) q4:-q4$ 
(C77) e1:tt*sada$ 

```

```

(C78) e4:e1+csad$
(C79) e5:e1-csad$
(C80) be1:matrix([0.5*(e1+abs(e1)),0,0,0,0],
[0,0.5*(e1+abs(e1)),0,0,0],
[0,0,0.5*(e1+abs(e1)),0,0],
[0,0,0,0.5*(e4+abs(e4)),0],
[0,0,0,0,0.5*(e5+abs(e5))])$
(C81) be2:matrix([0.5*(e1-abs(e1)),0,0,0,0],
[0,0.5*(e1-abs(e1)),0,0,0],
[0,0,0.5*(e1-abs(e1)),0,0],
[0,0,0,0.5*(e4-abs(e4)),0],
[0,0,0,0,0.5*(e5-abs(e5))])$
(C82) a:q1/(sqrt(2)*c)$
(C83) c1:0.5*rqrq$ 
(C84) c2:c*c/gm1$ 
(C85) br:matrix([axt,ayt,azt,a,a],
[q2*axt,q2*ayt-q1*azt,q2*azt+q1*ayt,a*(q2+c*axt),a*(q2-c*axt)],
[q3*axt+q1*azt,q3*ayt,q3*azt-q1*axt,a*(q3+c*ayt),a*(q3-c*ayt)],
[q4*axt-q1*ayt,q4*ayt+q1*axt,q4*azt,a*(q4+c*azt),a*(q4-c*azt)],
[c1*axt+q1*(q3*azt-q4*ayt),c1*ayt+q1*(q4*axt-q2*azt),
c1*azt+q1*(q2*ayt-q3*azt),a*(c1+c2+c*tt),a*(c1+c2-c*tt)])$
(C86) phi:0.5*gm1*rqrq$ 
(C87) c2:c*c$ 
(C88) b:1/(sqrt(2)*rc)$ 
(C89) c1:1-phi/c2$ 
(C90) c3:gm1/c2$ 
(C91) bl:matrix([axt*c1+q6*(q4*ayt-q3*azt),axt*q2*c3,axt*q3*c3+azt
*q6,
axt*q4*c3-ayt*q6,-axt*c3],
[ayt*c1+q6*(q2*azt-q4*axt),ayt*q2*c3-azt*q6,ayt*q3*c3,
ayt*q4*c3+axt*q6,-ayt*c3],
[azt*c1+q6*(q3*axt-q2*ayt),azt*q2*c3+ayt*q6,azt*q3*c3-azt*q6,
azt*q4*c3,-azt*c3],
[b*(phi-c*tt),b*(c*axt-q2*gm1),b*(c*ayt-q3*gm1),b*(c*azt-q4*gm1),
b*gm1],
[b*(phi+c*tt),-b*(c*axt+q2*gm1),-b*(c*ayt+q3*gm1),-b*(c*azt+q4*gm1
),
b*gm1])$ 
(C92) sp:bl.dq$ 
(C93) sp2:be1.sp$ 
(C94) sp:bl.dq$ 
(C95) sm2:be2.sp$ 
(C96) g:br.sm2-br.sp2$ 
(C97) tl:(qm[2]*ax+qm[3]*ay+qm[4]*az)/qm[1]$ 
(C98) g[1]:qm[1]*tl+g[1]$ 
(C99) g[2]:qm[2]*tl+ax*qm[6]+g[2]$ 
(C100) g[3]:qm[3]*tl+ay*qm[6]+g[3]$ 
(C101) g[4]:qm[4]*tl+az*qm[6]+g[4]$ 
(C102) g[5]:(qm[5]+qm[6])*tl+g[5]$ 
(C103) tl:(qp[2]*ax+qp[3]*ay+qp[4]*az)/qp[1]$ 
(C104) ghatijk[1]:0.5*(qp[1]*tl+g[1])$ 

```

GFLUX2

```
(C105) ghatijk[2]:=0.5*(qp[2]*tl+ax*qp[6]+g[2])$  
(C106) ghatijk[3]:=0.5*(qp[3]*tl+ay*qp[6]+g[3])$  
(C107) ghatijk[4]:=0.5*(qp[4]*tl+az*qp[6]+g[4])$  
(C108) ghatijk[5]:=0.5*((qp[5]+qp[6])*tl+g[5])$  
(C109) diff:gijk-m.ghatijk$  
(C110) diff:ratexpand(diff);  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
(D110)  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
[ 0 ]  
[ ]  
(C111) closefile(gflux2)$
```

```

(C3) diff:matrix([0],[0],[0],[0],[0])$
(C4) gsijk:matrix([0],[0],[0],[0],[0])$
(C5) gshijk:matrix([0],[0],[0],[0],[0])$
(C6) ax:etx$
(C7) ay:ety$
(C8) az:etz$
(C9) axt:ax/sada$
(C10) ayt:ay/sada$
(C11) azt:az/sada$
(C12) ra:.5*(r+rpl)$
(C13) pa:.5*(p+ppl)$
(C14) emu:(gam*abs(pa/ra))**0.666$
(C15) cons:fsmach/rel$
(C16) rpr:pr*emu$
(C17) vav:0.5*(volpl+vol)$
(C18) u2:rupl/rpl-ru/r$
(C19) v2:rvp1/rpl-rv/r$
(C20) w2:rwp1/rpl-rw/r$
(C21) t2:gam*(ppl/rpl-p/r)$
(C22) sigx:0.667*emu*cons*(2.*u2*ax-v2*ay-w2*az)/vav$
(C23) sigy:0.667*emu*cons*(2.*v2*ay-u2*ax-w2*az)/vav$
(C24) sigz:0.667*emu*cons*(2.*w2*az-u2*ax-v2*ay)/vav$
(C25) txy:emu*cons*(u2*ay+v2*ax)/vav$
(C26) txz:emu*cons*(u2*az+w2*ax)/vav$
(C27) tyz:emu*cons*(v2*az+w2*ay)/vav$
(C28) qx:-cons*rpr*rgm1*t2*ax/vav$
(C29) qy:-cons*rpr*rgm1*t2*ay/vav$
(C30) qz:-cons*rpr*rgm1*t2*az/vav$
(C31) gsijk[1,1]:0.0$
(C32) gsijk[2,1]:ax*sigx+ay*txy+az*txz$
(C33) gsijk[3,1]:ax*txy+ay*sigy+az*tyz$
(C34) gsijk[4,1]:ax*txz+ay*tyz+az*sigz$
(C35) ua:0.5*(rupl/rpl+ru/r)$
(C36) va:0.5*(rvpl/rpl+rv/r)$
(C37) wa:0.5*(rwpl/rpl+rw/r)$
(C38) gsijk[5,1]:ua*gsijk[2,1]+va*gsijk[3,1]+wa*gsijk[4,1]-qx*ax-q
y*ay-qz*az$
(C39) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0
,0,0,1])$
(C40) ax:etx$
(C41) ay:ety$
(C42) az:-etz$
(C43) axt:ax/sada$
(C44) ayt:ay/sada$
(C45) azt:az/sada$
(C46) rw:-rw$
(C47) rwpl:-rwpl$
(C48) rwm1:-rwm1$
(C49) ra:.5*(r+rpl)$
(C50) pa:.5*(p+ppl)$
(C51) emu:(gam*abs(pa/ra))**0.666$

```

```

(C52) cons:fsmach/rel$  

(C53) rpr:pr*emu$  

(C54) vav:0.5*(volp1+vol)$  

(C55) u2:rup1/rp1-ru/r$  

(C56) v2:rvp1/rp1-rv/r$  

(C57) w2:rwp1/rp1-rw/r$  

(C58) t2:gam*(pp1/rp1-p/r)$  

(C59) sigx:0.667*emu*cons*(2.*u2*ax-v2*ay-w2*az)/vav$  

(C60) sigy:0.667*emu*cons*(2.*v2*ay-u2*ax-w2*az)/vav$  

(C61) sigz:0.667*emu*cons*(2.*w2*az-u2*ax-v2*ay)/vav$  

(C62) txy:emu*cons*(u2*ay+v2*ax)/vav$  

(C63) txz:emu*cons*(u2*az+w2*ax)/vav$  

(C64) tyz:emu*cons*(v2*az+w2*ay)/vav$  

(C65) qx:-cons*rpr*rgm1*t2*ax/vav$  

(C66) qy:-cons*rpr*rgm1*t2*ay/vav$  

(C67) qz:-cons*rpr*rgm1*t2*az/vav$  

(C68) gshijk[1,1]:0.0$  

(C69) gshijk[2,1]:ax*sigx+ay*txy+az*txz$  

(C70) gshijk[3,1]:ax*txy+ay*sigy+az*tyz$  

(C71) gshijk[4,1]:ax*txz+ay*tyz+az*sigz$  

(C72) ua:0.5*(rup1/rp1+ru/r)$  

(C73) va:0.5*(rvp1/rp1+rv/r)$  

(C74) wa:0.5*(rwp1/rp1+rw/r)$  

(C75) gshijk[5,1]:ua*gshijk[2,1]+va*gshijk[3,1]+wa*gshijk[4,1]-qx*  

ax-qy*ay-qz*az$  

(C76) diff:gsijk-m.gshijk$  

(C77) diff:ratexpand(diff);

```

(D77)

```

[ 0 ]
[   ]
[ 0 ]
[   ]
[ 0 ]
[   ]
[ 0 ]
[   ]
[ 0 ]

```

(C78) closefile(gflux3)\$

```

(C3) diff:matrix([0],[0],[0],[0],[0])$ 
(C4) h:matrix([0],[0],[0],[0],[0])$ 
(C5) hijk:matrix([0],[0],[0],[0],[0])$ 
(C6) hhatijk:matrix([0],[0],[0],[0],[0])$ 
(C7) null:matrix([0],[0],[0],[0],[0])$ 
(C8) xy2:matrix([0],[0],[0],[0],[0])$ 
(C9) x2y:matrix([0],[0],[0],[0],[0])$ 
(C10) xpy:matrix([0],[0],[0],[0],[0])$ 
(C11) sp1:matrix([0],[0],[0],[0],[0])$ 
(C12) sp2:matrix([0],[0],[0],[0],[0])$ 
(C13) sm1:matrix([0],[0],[0],[0],[0])$ 
(C14) sm2:matrix([0],[0],[0],[0],[0])$ 
(C15) ax:ztx$ 
(C16) ay:zty$ 
(C17) az:ztz$ 
(C18) dq:matrix([rp1-r],[rup1-ru],[rvp1-rv],[rwpl-rw],[ep1-e],[pp1-p])$ 
(C19) dqm1:matrix([r-rm1],[ru-rum1],[rv-rvm1],[rw-rwm1],[e-em1],[p-pm1])$ 
(C20) dqp1:matrix([rp2-rp1],[rup2-rup1],[rvp2-rvp1],[rwp2-rwp1],[e2-ep1],[pp2-pp1])$ 
(C21) qp:matrix([rp1],[rup1],[rvp1],[rwpl],[ep1],[pp1])$ 
(C22) qm:matrix([r],[ru],[rv],[rw],[e],[p])$ 
(C23) for i: 1 thru 6 do 
xy2[i]:=dqm1[i]*(dq[i]*dq[i]+eps)$ 
(C24) for i:1 thru 6 do 
x2y[i]:=dq[i]*(dqm1[i]*dqm1[i]+eps)$ 
(C25) for i:1 thru 6 do 
xpy[i]:=dqm1[i]*dqm1[i] + dq[i]*dq[i]$ 
(C26) for i:1 thru 6 do 
sm1[i]:=(x2y[i]+xy2[i])/ (xpy[i]+2*eps)$ 
(C27) for i: 1 thru 6 do 
xy2[i]:=dqp1[i]*(dq[i]*dq[i]+eps)$ 
(C28) for i:1 thru 6 do 
x2y[i]:=dq[i]*(dqp1[i]*dqp1[i]+eps)$ 
(C29) for i:1 thru 6 do 
xpy[i]:=dqp1[i]*dqp1[i] + dq[i]*dq[i]$ 
(C30) for i:1 thru 6 do 
sp1[i]:=(x2y[i]+xy2[i])/ (xpy[i]+2*eps)$ 
(C31) m:matrix([1,0,0,0,0,0],[0,1,0,0,0,0],[0,0,1,0,0,0],[0,0,0,-1,0,0],[0,0,0,0,1,0],[0,0,0,0,0,1])$ 
(C32) ax:-ztx$ 
(C33) ay:-zty$ 
(C34) az:ztz$ 
(C35) dqo:dq$ 
(C36) dqm1o:dqm1$ 
(C37) dqp1o:dqp1$ 
(C38) qpo:qp$ 
(C39) qmo:qm$ 
(C40) dq:-M.dqo$ 

```

```

(C41) dqm1:-M.dqp1o$  

(C42) dqp1:-M.dqm1o$  

(C43) qp:M.qm$  

(C44) qm:M.qp$  

(C45) for i: 1 thru 6 do  

xy2[i]: dqm1[i]*(dq[i]*dq[i]+eps)$  

(C46) for i:1 thru 6 do  

x2y[i]: dq[i]*(dqm1[i]*dqm1[i]+eps)$  

(C47) for i:1 thru 6 do  

xpy[i]: dqm1[i]*dqm1[i] + dq[i]*dq[i]$  

(C48) for i:1 thru 6 do  

sm2[i]: (x2y[i]+xy2[i])/(xpy[i]+2*eps)$  

(C49) for i: 1 thru 6 do  

xy2[i]: dqp1[i]*(dq[i]*dq[i]+eps)$  

(C50) for i:1 thru 6 do  

x2y[i]: dq[i]*(dqp1[i]*dqp1[i]+eps)$  

(C51) for i:1 thru 6 do  

xpy[i]: dqp1[i]*dqp1[i] + dq[i]*dq[i]$  

(C52) for i:1 thru 6 do  

sp2[i]: (x2y[i]+xy2[i])/(xpy[i]+2*eps)$  

(C53) diff1:sp1+m.sm2$  

(C54) diff1:ratexpand(diff1);  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

(D54) [ 0 ]  

[ ]  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

(C55) diff2:sm1+m.sp2$  

(C56) diff2:ratexpand(diff2);  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

(D56) [ 0 ]  

[ ]  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

[ 0 ]  

[ ]  

(C57) closefile(hflux1)$

```

```

(C3) diff:matrix([0],[0],[0],[0],[0])$ 
(C4) h:matrix([0],[0],[0],[0],[0])$ 
(C5) hijk:matrix([0],[0],[0],[0],[0])$ 
(C6) hhatijk:matrix([0],[0],[0],[0],[0])$ 
(C7) sp:matrix([0],[0],[0],[0],[0])$ 
(C8) dq:matrix([0],[0],[0],[0],[0])$ 
(C9) null:matrix([0],[0],[0],[0],[0])$ 
(C10) xy2:matrix([0],[0],[0],[0],[0],[0])$ 
(C11) x2y:matrix([0],[0],[0],[0],[0],[0])$ 
(C12) xpy:matrix([0],[0],[0],[0],[0],[0])$ 
(C13) sp1:matrix([0],[0],[0],[0],[0])$ 
(C14) sp2:matrix([0],[0],[0],[0],[0])$ 
(C15) sm1:matrix([0],[0],[0],[0],[0])$ 
(C16) sm2:matrix([0],[0],[0],[0],[0])$ 
(C17) ax:ztx$ 
(C18) ay:zty$ 
(C19) az:ztz$ 
(C20) axt:ax/sada$ 
(C21) ayt:ay/sada$ 
(C22) azt:az/sada$ 
(C23) dq:matrix([dq1],[dq2],[dq3],[dq4],[dq5])$ 
(C24) qp:matrix([qp1],[qp2],[qp3],[qp4],[qp5],[qp6])$ 
(C25) qm:matrix([qm1],[qm2],[qm3],[qm4],[qm5],[qm6])$ 
(C26) e1:tt*sada$ 
(C27) e4:e1+csad$ 
(C28) e5:e1-csad$ 
(C29) be1:matrix([0.5*(e1+abs(e1)),0,0,0,0], 
[0,0.5*(e1+abs(e1)),0,0,0], 
[0,0,0.5*(e1+abs(e1)),0,0], 
[0,0,0,0.5*(e4+abs(e4)),0], 
[0,0,0,0,0.5*(e5+abs(e5))])$ 
(C30) be2:matrix([0.5*(e1-abs(e1)),0,0,0,0], 
[0,0.5*(e1-abs(e1)),0,0,0], 
[0,0,0.5*(e1-abs(e1)),0,0], 
[0,0,0,0.5*(e4-abs(e4)),0], 
[0,0,0,0,0.5*(e5-abs(e5))])$ 
(C31) a:q1/(sqrt(2)*c)$ 
(C32) c1:0.5*rqrq$ 
(C33) c2:c*c/gm1$ 
(C34) br:matrix([axt,ayt,azt,a,a], 
[q2*axt,q2*ayt-q1*azt,q2*azt+q1*ayt,a*(q2+c*axt),a*(q2-c*axt)], 
[q3*axt+q1*azt,q3*ayt,q3*azt-q1*axt,a*(q3+c*ayt),a*(q3-c*ayt)], 
[q4*axt-q1*ayt,q4*ayt+q1*axt,q4*azt,a*(q4+c*azt),a*(q4-c*azt)], 
[c1*axt+q1*(q3*azt-q4*ayt),c1*ayt+q1*(q4*axt-q2*azt), 
c1*azt+q1*(q2*ayt-q3*axt),a*(c1+c2+c*tt),a*(c1+c2-c*tt)])$ 
(C35) phi:0.5*gm1*rqrq$ 
(C36) c2:c*c$ 
(C37) b:1/(sqrt(2)*rc)$ 
(C38) c1:1-phi/c2$ 
(C39) c3:gm1/c2$ 
(C40) bl:matrix([axt*c1+q6*(q4*ayt-q3*azt),axt*q2*c3,axt*q3*c3+azt

```

```

*q6,
axt*q4*c3-ayt*q6,-axt*c3],
[ayt*c1+q6*(q2*azt-q4*axt),ayt*q2*c3-azt*q6,ayt*q3*c3,
ayt*q4*c3+axt*q6,-ayt*c3],
[azt*c1+q6*(q3*axt-q2*ayt),azt*q2*c3+ayt*q6,azt*q3*c3-axt*q6,
azt*q4*c3,-azt*c3],
[b*(phi-c*tt),b*(c*axt-q2*gm1),b*(c*ayt-q3*gm1),b*(c*azt-q4*gm1),
b*gm1],
[b*(phi+c*tt),-b*(c*axt+q2*gm1),-b*(c*ayt+q3*gm1),-b*(c*azt+q4*gm1
),
b*gm1])$  

(C41) sp:bl.dq$  

(C42) sp2:be1.sp$  

(C43) sp:bl.dq$  

(C44) sm2:be2.sp$  

(C45) h:br.sm2-br.sp2$  

(C46) tl:(qm[2]*ax+qm[3]*ay+qm[4]*az)/qm[1]$  

(C47) h[1]:qm[1]*tl+h[1]$  

(C48) h[2]:qm[2]*tl+ax*qm[6]+h[2]$  

(C49) h[3]:qm[3]*tl+ay*qm[6]+h[3]$  

(C50) h[4]:qm[4]*tl+az*qm[6]+h[4]$  

(C51) h[5]: (qm[5]+qm[6])*tl+h[5]$  

(C52) tl:(qp[2]*ax+qp[3]*ay+qp[4]*az)/qp[1]$  

(C53) hijk[1]:0.5*(qp[1]*tl+h[1])$  

(C54) hijk[2]:0.5*(qp[2]*tl+ax*qp[6]+h[2])$  

(C55) hijk[3]:0.5*(qp[3]*tl+ay*qp[6]+h[3])$  

(C56) hijk[4]:0.5*(qp[4]*tl+az*qp[6]+h[4])$  

(C57) hijk[5]:0.5*((qp[5]+qp[6])*tl+h[5])$  

(C58) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0
,0,0,0,1])$  

(C59) m2:matrix([1,0,0,0,0,0],[0,1,0,0,0,0],[0,0,1,0,0,0],[0,0,0,-
1,0,0],
[0,0,0,1,0],[0,0,0,0,0,1])$  

(C60) ax:-ztx$  

(C61) ay:-zty$  

(C62) az:ztz$  

(C63) axt:ax/sada$  

(C64) ayt:ay/sada$  

(C65) azt:az/sada$  

(C66) dqa:dq$  

(C67) qpo:qp$  

(C68) qmo:qm$  

(C69) dq:-m.dqa$  

(C70) qp:m2.qmo$  

(C71) qm:m2.qpo$  

(C72) q4:-q4$  

(C73) tt:-tt$  

(C74) e1:tt*sada$  

(C75) e4:e1+csad$  

(C76) e5:e1-csad$  

(C77) be1:matrix([0.5*(e1+abs(e1)),0,0,0,0],

```

```

[0,0,0.5*(e1+abs(e1)),0,0,0],
[0,0,0.5*(e1+abs(e1)),0,0,0],
[0,0,0,0.5*(e4+abs(e4)),0],
[0,0,0,0,0.5*(e5+abs(e5)))]$  

(C78) be2:matrix([0.5*(e1-abs(e1)),0,0,0,0],
[0,0.5*(e1-abs(e1)),0,0,0],
[0,0,0.5*(e1-abs(e1)),0,0,0],
[0,0,0,0.5*(e4-abs(e4)),0],
[0,0,0,0,0.5*(e5-abs(e5))])$  

(C79) a:q1/(sqrt(2)*c)$  

(C80) c1:0.5*rqrq$  

(C81) c2:c*c/gm1$  

(C82) br:matrix([axt,ayt,azt,a,a],
[q2*axt,q2*ayt-q1*azt,q2*azt+q1*ayt,a*(q2+c*axt),a*(q2-c*axt)],
[q3*axt+q1*azt,q3*ayt,q3*azt-q1*axt,a*(q3+c*ayt),a*(q3-c*ayt)],
[q4*axt-q1*ayt,q4*ayt+q1*axt,q4*azt,a*(q4+c*azt),a*(q4-c*azt)],
[c1*axt+q1*(q3*azt-q4*ayt),c1*ayt+q1*(q4*axt-q2*azt),
c1*azt+q1*(q2*ayt-q3*azt),a*(c1+c2+c*tt),a*(c1+c2-c*tt)])$  

(C83) phi:0.5*gm1*rqrq$  

(C84) c2:c*c$  

(C85) b:1/(sqrt(2)*rc)$  

(C86) c1:1-phi/c2$  

(C87) c3:gm1/c2$  

(C88) bl:matrix([axt*c1+q6*(q4*ayt-q3*azt),axt*q2*c3,axt*q3*c3+azt
*q6,
axt*q4*c3-ayt*q6,-axt*c3],
[ayt*c1+q6*(q2*azt-q4*axt),ayt*q2*c3-azt*q6,ayt*q3*c3,
ayt*q4*c3+axt*q6,-ayt*c3],
[azt*c1+q6*(q3*axt-q2*ayt),azt*q2*c3+ayt*q6,azt*q3*c3-azt*q6,
azt*q4*c3,-azt*c3],
[b*(phi-c*tt),b*(c*axt-q2*gm1),b*(c*ayt-q3*gm1),b*(c*azt-q4*gm1),
b*gm1],
[b*(phi+c*tt),-b*(c*axt+q2*gm1),-b*(c*ayt+q3*gm1),-b*(c*azt+q4*gm1
),
b*gm1])$  

(C89) sp:bl.dq$  

(C90) sp2:be1.sp$  

(C91) sp:bl.dq$  

(C92) sm2:be2.sp$  

(C93) h:br.sm2-br.sp2$  

(C94) tl:(qm[2]*ax+qm[3]*ay+qm[4]*az)/qm[1]$  

(C95) h[1]:qm[1]*tl+h[1]$  

(C96) h[2]:qm[2]*tl+ax*qm[6]+h[2]$  

(C97) h[3]:qm[3]*tl+ay*qm[6]+h[3]$  

(C98) h[4]:qm[4]*tl+az*qm[6]+h[4]$  

(C99) h[5]:(qm[5]+qm[6])*tl+h[5]$  

(C100) tl:(qp[2]*ax+qp[3]*ay+qp[4]*az)/qp[1]$  

(C101) hhatijk[1]:0.5*(qp[1]*tl+h[1])$  

(C102) hhatijk[2]:0.5*(qp[2]*tl+ax*qp[6]+h[2])$  

(C103) hhatijk[3]:0.5*(qp[3]*tl+ay*qp[6]+h[3])$  

(C104) hhatijk[4]:0.5*(qp[4]*tl+az*qp[6]+h[4])$
```

HFLUX2

```
(C105) hhatijk[5]:0.5*((qp[5]+qp[6])*t1+h[5])$  
(C106) diff:hijk+m.hhatijk$  
(C107) diff:ratexpand(diff);  
          [ 0 ]  
          [ ]  
          [ 0 ]  
          [ ]  
          [ 0 ]  
          [ ]  
          [ 0 ]  
          [ ]  
          [ 0 ]  
          [ ]  
(D107)  
          [ 0 ]  
  
(C108) closefile(hflux2)$
```

```

(C3) ap1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C6) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C7) sign:1$
(C8) cgg1:(gam-1)/gam$
(C9) cgg2:1/(2*gam)$
(C10) xiy:0.0$
(C11) xiz:0.0$
(C12) sada:sqrt(xix**2+xiy**2+xiz**2)$
(C13) axt:xix/sada$
(C14) ayt:xiy/sada$
(C15) azt:xiz/sada$
(C16) rqrq:q2**2+q3**2+q4**2$
(C17) q6:1/q1$
(C18) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C19) prgam:pr*gam$
(C20) pp:q5+pr$
(C21) c:sqrt(prgam*q6)$
(C22) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C23) rc:q1*c$
(C24) csad:c*sada$
(C25) e1:tt*sada$
(C26) e4:e1+csad$
(C27) e5:e1-csad$
(C28) ev1:0.5*(e1+sign*abs(e1))$
(C29) ev4:0.5*(e4+sign*abs(e4))$
(C30) ev5:0.5*(e5+sign*abs(e5))$
(C31) cg1:cgg1$
(C32) cg2:cgg2$
(C33) cg3:cgg2$
(C34) d1q1:-ev1*q6$
(C35) d1q2:xix*q6$
(C36) d1q3:xiy*q6$
(C37) d1q4:xiz*q6$
(C38) d1q5:0.0$
(C39) coe:gam*(gam-1)/(2*rc)$
(C40) gm1q6:(gam-1)*q6$
(C41) drcq1:coe*q5$
(C42) drcq2:-coe*q2$
(C43) drcq3:-coe*q3$
(C44) drcq4:-coe*q4$
(C45) drcq5:coe*q1$
(C46) dcq1:(drcq1-c)*q6$
(C47) dcq2:drcq2*q6$
(C48) dcq3:drcq3*q6$
(C49) dcq4:drcq4*q6$

```

(C50) dcq5:drcq5*q6\$
(C51) depq1:0.5*gm1q6*rqrq*q6\$
(C52) depq2:-q2*gm1q6\$
(C53) depq3:-q3*gm1q6\$
(C54) depq4:-q4*gm1q6\$
(C55) depq5:gam\$
(C56) dttq1:-tt*q6\$
(C57) dttq2:axt*q6\$
(C58) dttq3:ayt*q6\$
(C59) dttq4:azt*q6\$
(C60) dttq5:0.0\$
(C61) d4q1:sada*(dttq1+dcq1)\$
(C62) d4q2:sada*(dttq2+dcq2)\$
(C63) d4q3:sada*(dttq3+dcq3)\$
(C64) d4q4:sada*(dttq4+dcq4)\$
(C65) d4q5:sada*dcq5\$
(C66) d5q1:sada*(dttq1-dcq1)\$
(C67) d5q2:sada*(dttq2-dcq2)\$
(C68) d5q3:sada*(dttq3-dcq3)\$
(C69) d5q4:sada*(dttq4-dcq4)\$
(C70) d5q5:-d4q5\$
(C71) a411:ev4+q1*d4q1\$
(C72) a511:ev5+q1*d5q1\$
(C73) ap1[1,1]:cg2*a411+cg3*a511\$
(C74) ap1[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C75) ap1[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C76) ap1[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C77) ap1[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C78) rcaxt:rc*axt\$
(C79) ev4ax:ev4*axt\$
(C80) ev5ax:ev5*axt\$
(C81) coe1:q2+rcaxt\$
(C82) coe:q2-rcaxt\$
(C83) a121:q2*d1q1\$
(C84) a421:ev4ax*drcq1+coe1*d4q1\$
(C85) a521:-ev5ax*drcq1+coe*d5q1\$
(C86) ap1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C87) a122:q2*d1q2+ev1\$
(C88) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C89) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C90) ap1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C91) a123:q2*d1q3\$
(C92) a423:ev4ax*drcq3+coe1*d4q3\$
(C93) a523:-ev5ax*drcq3+coe*d5q3\$
(C94) ap1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C95) a124:q2*d1q4\$
(C96) a424:ev4ax*drcq4+coe1*d4q4\$
(C97) a524:-ev5ax*drcq4+coe*d5q4\$
(C98) ap1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C99) a125:q2*d1q5\$
(C100) a425:ev4ax*drcq5+coe1*d4q5\$

(C101) a525:-ev5ax*drcq5+coe*d5q5\$
(C102) ap1[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C103) rcayt:rc*ayt\$
(C104) ev4ay:ev4*ayt\$
(C105) ev5ay:ev5*ayt\$
(C106) coe1:q3+rcayt\$
(C107) coe:q3-rcayt\$
(C108) a131:q3*d1q1\$
(C109) a431:ev4ay*drcq1+coe1*d4q1\$
(C110) a531:-ev5ay*drcq1+coe*d5q1\$
(C111) ap1[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C112) a132:q3*d1q2\$
(C113) a432:ev4ay*drcq2+coe1*d4q2\$
(C114) a532:-ev5ay*drcq2+coe*d5q2\$
(C115) ap1[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C116) a133:q3*d1q3+ev1\$
(C117) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C118) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C119) ap1[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C120) a134:q3*d1q4\$
(C121) a434:ev4ay*drcq4+coe1*d4q4\$
(C122) a534:-ev5ay*drcq4+coe*d5q4\$
(C123) ap1[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C124) a135:q3*d1q5\$
(C125) a435:ev4ay*drcq5+coe1*d4q5\$
(C126) a535:-ev5ay*drcq5+coe*d5q5\$
(C127) ap1[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C128) rcazt:rc*azt\$
(C129) ev4az:ev4*azt\$
(C130) ev5az:ev5*azt\$
(C131) coe1:q4+rcazt\$
(C132) coe:q4-rcazt\$
(C133) a141:q4*d1q1\$
(C134) a441:ev4az*drcq1+coe1*d4q1\$
(C135) a541:-ev5az*drcq1+coe*d5q1\$
(C136) ap1[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C137) a142:q4*d1q2\$
(C138) a442:ev4az*drcq2+coe1*d4q2\$
(C139) a542:-ev5az*drcq2+coe*d5q2\$
(C140) ap1[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C141) a143:q4*d1q3\$
(C142) a443:ev4az*drcq3+coe1*d4q3\$
(C143) a543:-ev5az*drcq3+coe*d5q3\$
(C144) ap1[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C145) a144:q4*d1q4+ev1\$
(C146) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C147) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C148) ap1[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C149) a145:q4*d1q5\$
(C150) a445:ev4az*drcq5+coe1*d4q5\$
(C151) a545:-ev5az*drcq5+coe*d5q5\$

(C152) ap1[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C153) rctt:rc*tt\$
(C154) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C155) rt:rc*dttq1+tt*drcq1\$
(C156) a151:2*coe*d1q1\$
(C157) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C158) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C159) ap1[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C160) rt:rc*dttq2+tt*drcq2\$
(C161) a152:coe*d1q2-d1q1*q2\$
(C162) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C163) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C164) ap1[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C165) rt:rc*dttq3+tt*drcq3\$
(C166) a153:coe*d1q3-d1q1*q3\$
(C167) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C168) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C169) ap1[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C170) rt:rc*dttq4+tt*drcq4\$
(C171) a154:coe*d1q4-d1q1*q4\$
(C172) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C173) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C174) ap1[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C175) rt:tt*drcq5\$
(C176) a155:coe*d1q5\$
(C177) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C178) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C179) ap1[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C180) q1:q1\$
(C181) q2:q2\$
(C182) q3:q3\$
(C183) q4:-q4\$
(C184) q5:q5\$
(C185) sign:1\$
(C186) cgg1:(gam-1)/gam\$
(C187) cgg2:1/(2*gam)\$
(C188) sada:sqrt(xix**2+xiy**2+xiz**2)\$
(C189) axt:xix/sada\$
(C190) ayt:xiy/sada\$
(C191) azt:xiz/sada\$
(C192) rqrq:q2**2+q3**2+q4**2\$
(C193) q6:1/q1\$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C195) prgam:pr*gam\$
(C196) pp:q5+pr\$
(C197) c:sqrt(prgam*q6)\$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C199) rc:q1*c\$
(C200) csad:c*sada\$
(C201) e1:tt*sada\$
(C202) e4:e1+csad\$

```

(C203) e5:e1-csad$
(C204) ev1:0.5*(e1+sign*abs(e1))$
(C205) ev4:0.5*(e4+sign*abs(e4))$
(C206) ev5:0.5*(e5+sign*abs(e5))$
(C207) cg1:cgg1$
(C208) cg2:cgg2$
(C209) cg3:cgg2$
(C210) d1q1:-ev1*q6$
(C211) d1q2:xix*q6$
(C212) d1q3:xiy*q6$
(C213) d1q4:xiz*q6$
(C214) d1q5:0.0$
(C215) coe:gam*(gam-1)/(2*rc)$
(C216) gmlq6:(gam-1)*q6$
(C217) drcq1:coe*q5$
(C218) drcq2:-coe*q2$
(C219) drcq3:-coe*q3$
(C220) drcq4:-coe*q4$
(C221) drcq5:coe*q1$
(C222) dcq1:(drcq1-c)*q6$
(C223) dcq2:drcq2*q6$
(C224) dcq3:drcq3*q6$
(C225) dcq4:drcq4*q6$
(C226) dcq5:drcq5*q6$
(C227) depq1:0.5*gmlq6*rqrq*q6$
(C228) depq2:-q2*gmlq6$
(C229) depq3:-q3*gmlq6$
(C230) depq4:-q4*gmlq6$
(C231) depq5:gam$
(C232) dttq1:-tt*q6$
(C233) dttq2:axt*q6$
(C234) dttq3:ayt*q6$
(C235) dttq4:azt*q6$
(C236) dttq5:0.0$
(C237) d4q1:sada*(dttq1+dcq1)$
(C238) d4q2:sada*(dttq2+dcq2)$
(C239) d4q3:sada*(dttq3+dcq3)$
(C240) d4q4:sada*(dttq4+dcq4)$
(C241) d4q5:sada*dcq5$
(C242) d5q1:sada*(dttq1-dcq1)$
(C243) d5q2:sada*(dttq2-dcq2)$
(C244) d5q3:sada*(dttq3-dcq3)$
(C245) d5q4:sada*(dttq4-dcq4)$
(C246) d5q5:-d4q5$
(C247) a411:ev4+q1*d4q1$
(C248) a511:ev5+q1*d5q1$
(C249) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],
[0,0,0,0,0])$
(C250) ap2[1,1]:cg2*a411+cg3*a511$
(C251) ap2[1,2]:(cg1*d1q2+cg2*d4q2+cq3*d5q2)*q1$
(C252) ap2[1,3]:(cg1*d1q3+cg2*d4q3+cq3*d5q3)*q1$

```

(C253) ap2[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C254) ap2[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C255) rcaxt:rc*axt\$\n
(C256) ev4ax:ev4*axt\$\n
(C257) ev5ax:ev5*axt\$\n
(C258) coe1:q2+rcaxt\$\n
(C259) coe:q2-rcaxt\$\n
(C260) a121:q2*d1q1\$\n
(C261) a421:ev4ax*drcq1+coe1*d4q1\$\n
(C262) a521:-ev5ax*drcq1+coe*d5q1\$\n
(C263) ap2[2,1]:cg1*a121+cg2*a421+cg3*a521\$\n
(C264) a122:q2*d1q2+ev1\$\n
(C265) a422:ev4+ev4ax*drcq2+coe1*d4q2\$\n
(C266) a522:ev5-ev5ax*drcq2+coe*d5q2\$\n
(C267) ap2[2,2]:cg1*a122+cg2*a422+cg3*a522\$\n
(C268) a123:q2*d1q3\$\n
(C269) a423:ev4ax*drcq3+coe1*d4q3\$\n
(C270) a523:-ev5ax*drcq3+coe*d5q3\$\n
(C271) ap2[2,3]:cg1*a123+cg2*a423+cg3*a523\$\n
(C272) a124:q2*d1q4\$\n
(C273) a424:ev4ax*drcq4+coe1*d4q4\$\n
(C274) a524:-ev5ax*drcq4+coe*d5q4\$\n
(C275) ap2[2,4]:cg1*a124+cg2*a424+cg3*a524\$\n
(C276) a125:q2*d1q5\$\n
(C277) a425:ev4ax*drcq5+coe1*d4q5\$\n
(C278) a525:-ev5ax*drcq5+coe*d5q5\$\n
(C279) ap2[2,5]:cg1*a125+cg2*a425+cg3*a525\$\n
(C280) rcayt:rc*ayt\$\n
(C281) ev4ay:ev4*ayt\$\n
(C282) ev5ay:ev5*ayt\$\n
(C283) coe1:q3+rcayt\$\n
(C284) coe:q3-rcayt\$\n
(C285) a131:q3*d1q1\$\n
(C286) a431:ev4ay*drcq1+coe1*d4q1\$\n
(C287) a531:-ev5ay*drcq1+coe*d5q1\$\n
(C288) ap2[3,1]:cg1*a131+cg2*a431+cg3*a531\$\n
(C289) a132:q3*d1q2\$\n
(C290) a432:ev4ay*drcq2+coe1*d4q2\$\n
(C291) a532:-ev5ay*drcq2+coe*d5q2\$\n
(C292) ap2[3,2]:cg1*a132+cg2*a432+cg3*a532\$\n
(C293) a133:q3*d1q3+ev1\$\n
(C294) a433:ev4+ev4ay*drcq3+coe1*d4q3\$\n
(C295) a533:ev5-ev5ay*drcq3+coe*d5q3\$\n
(C296) ap2[3,3]:cg1*a133+cg2*a433+cg3*a533\$\n
(C297) a134:q3*d1q4\$\n
(C298) a434:ev4ay*drcq4+coe1*d4q4\$\n
(C299) a534:-ev5ay*drcq4+coe*d5q4\$\n
(C300) ap2[3,4]:cg1*a134+cg2*a434+cg3*a534\$\n
(C301) a135:q3*d1q5\$\n
(C302) a435:ev4ay*drcq5+coe1*d4q5\$\n
(C303) a535:-ev5ay*drcq5+coe*d5q5\$

(C304) ap2[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C305) rcazt:rc*azt\$
(C306) ev4az:ev4*azt\$
(C307) ev5az:ev5*azt\$
(C308) coe1:q4+rcazt\$
(C309) coe:q4-rcazt\$
(C310) a141:q4*d1q1\$
(C311) a441:ev4az*drcq1+coe1*d4q1\$
(C312) a541:-ev5az*drcq1+coe*d5q1\$
(C313) ap2[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C314) a142:q4*d1q2\$
(C315) a442:ev4az*drcq2+coe1*d4q2\$
(C316) a542:-ev5az*drcq2+coe*d5q2\$
(C317) ap2[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C318) a143:q4*d1q3\$
(C319) a443:ev4az*drcq3+coe1*d4q3\$
(C320) a543:-ev5az*drcq3+coe*d5q3\$
(C321) ap2[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C322) a144:q4*d1q4+ev1\$
(C323) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C324) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C325) ap2[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C326) a145:q4*d1q5\$
(C327) a445:ev4az*drcq5+coe1*d4q5\$
(C328) a545:-ev5az*drcq5+coe*d5q5\$
(C329) ap2[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C330) rctt:rc*tt\$
(C331) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C332) rt:rc*dttq1+tt*drcq1\$
(C333) a151:2*coe*d1q1\$
(C334) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C335) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C336) ap2[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C337) rt:rc*dttq2+tt*drcq2\$
(C338) a152:coe*d1q2-d1q1*q2\$
(C339) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C340) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C341) ap2[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C342) rt:rc*dttq3+tt*drcq3\$
(C343) a153:coe*d1q3-d1q1*q3\$
(C344) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C345) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C346) ap2[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C347) rt:rc*dttq4+tt*drcq4\$
(C348) a154:coe*d1q4-d1q1*q4\$
(C349) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C350) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C351) ap2[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C352) rt:tt*drcq5\$
(C353) a155:coe*d1q5\$
(C354) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$

```
(C355) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5$  
(C356) ap2[5,5]:cg1*a155+cg2*a455+cg3*a555$  
(C357) diff:ap1.m-m.ap2$  
(C358) diff:ratexpand(diff);  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
(D358)  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
          [ 0   0   0   0   0 ]  
(C359) closefile(Apsup)$  
***
```

```

(C3) ap1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C6) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C7) sign:1$
(C8) cgg1:(gam-1)/gam$
(C9) cgg2:1/(2*gam)$
(C10) xiy:0.0$
(C11) xiz:0.0$
(C12) sada:sqrt(xix**2+xiy**2+xiz**2)$
(C13) axt:xix/sada$
(C14) ayt:xiy/sada$
(C15) azt:xiz/sada$
(C16) rqrq:q2**2+q3**2+q4**2$
(C17) q6:1/q1$
(C18) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C19) prgam:pr*gam$
(C20) pp:q5+pr$
(C21) c:sqrt(prgam*q6)$
(C22) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C23) rc:q1*c$
(C24) csad:c*sada$
(C25) e1:tt*sada$
(C26) e4:e1+csad$
(C27) e5:e1-csad$
(C28) ev1:0.5*(e1+sign*abs(e1))$
(C29) ev4:0.5*(e4+sign*abs(e4))$
(C30) ev5:0.0$
(C31) cg1:cgg1$
(C32) cg2:cgg2$
(C33) cg3:0.0$
(C34) d1q1:-ev1*q6$
(C35) d1q2:xix*q6$
(C36) d1q3:xiy*q6$
(C37) d1q4:xiz*q6$
(C38) d1q5:0.0$
(C39) coe:gam*(gam-1)/(2*rc)$
(C40) gm1q6:(gam-1)*q6$
(C41) drcq1:coe*q5$
(C42) drcq2:-coe*q2$
(C43) drcq3:-coe*q3$
(C44) drcq4:-coe*q4$
(C45) drcq5:coe*q1$
(C46) dcq1:(drcq1-c)*q6$
(C47) dcq2:drcq2*q6$
(C48) dcq3:drcq3*q6$
(C49) dcq4:drcq4*q6$

```

(C50) dcq5:drcq5*q6\$
(C51) depq1:0.5*gm1q6*rqrq*q6\$
(C52) depq2:-q2*gm1q6\$
(C53) depq3:-q3*gm1q6\$
(C54) depq4:-q4*gm1q6\$
(C55) depq5:gam\$
(C56) dttq1:-tt*q6\$
(C57) dttq2:axt*q6\$
(C58) dttq3:ayt*q6\$
(C59) dttq4:azt*q6\$
(C60) dttq5:0.0\$
(C61) d4q1:sada*(dttq1+dcq1)\$
(C62) d4q2:sada*(dttq2+dcq2)\$
(C63) d4q3:sada*(dttq3+dcq3)\$
(C64) d4q4:sada*(dttq4+dcq4)\$
(C65) d4q5:sada*dcq5\$
(C66) d5q1:sada*(dttq1-dcq1)\$
(C67) d5q2:sada*(dttq2-dcq2)\$
(C68) d5q3:sada*(dttq3-dcq3)\$
(C69) d5q4:sada*(dttq4-dcq4)\$
(C70) d5q5:-d4q5\$
(C71) a411:ev4+q1*d4q1\$
(C72) a511:ev5+q1*d5q1\$
(C73) ap1[1,1]:cg2*a411+cg3*a511\$
(C74) ap1[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C75) ap1[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C76) ap1[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C77) ap1[1,5]: (cg2*d4q5+cg3*d5q5)*q1\$
(C78) rcaxt:rc*axt\$
(C79) ev4ax:ev4*axt\$
(C80) ev5ax:ev5*axt\$
(C81) coe1:q2+rcaxt\$
(C82) coe:q2-rcaxt\$
(C83) a121:q2*d1q1\$
(C84) a421:ev4ax*drcq1+coe1*d4q1\$
(C85) a521:-ev5ax*drcq1+coe*d5q1\$
(C86) ap1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C87) a122:q2*d1q2+ev1\$
(C88) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C89) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C90) ap1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C91) a123:q2*d1q3\$
(C92) a423:ev4ax*drcq3+coe1*d4q3\$
(C93) a523:-ev5ax*drcq3+coe*d5q3\$
(C94) ap1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C95) a124:q2*d1q4\$
(C96) a424:ev4ax*drcq4+coe1*d4q4\$
(C97) a524:-ev5ax*drcq4+coe*d5q4\$
(C98) ap1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C99) a125:q2*d1q5\$
(C100) a425:ev4ax*drcq5+coe1*d4q5\$

(C101) a525:-ev5ax*drcq5+coe*d5q5\$
(C102) ap1[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C103) rcayt:rc*ayt\$
(C104) ev4ay:ev4*ayt\$
(C105) ev5ay:ev5*ayt\$
(C106) coe1:q3+rcayt\$
(C107) coe:q3-rcayt\$
(C108) a131:q3*d1q1\$
(C109) a431:ev4ay*drcq1+coe1*d4q1\$
(C110) a531:-ev5ay*drcq1+coe*d5q1\$
(C111) ap1[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C112) a132:q3*d1q2\$
(C113) a432:ev4ay*drcq2+coe1*d4q2\$
(C114) a532:-ev5ay*drcq2+coe*d5q2\$
(C115) ap1[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C116) a133:q3*d1q3+ev1\$
(C117) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C118) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C119) ap1[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C120) a134:q3*d1q4\$
(C121) a434:ev4ay*drcq4+coe1*d4q4\$
(C122) a534:-ev5ay*drcq4+coe*d5q4\$
(C123) ap1[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C124) a135:q3*d1q5\$
(C125) a435:ev4ay*drcq5+coe1*d4q5\$
(C126) a535:-ev5ay*drcq5+coe*d5q5\$
(C127) ap1[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C128) rcazt:rc*azt\$
(C129) ev4az:ev4*azt\$
(C130) ev5az:ev5*azt\$
(C131) coe1:q4+rcazt\$
(C132) coe:q4-rcazt\$
(C133) a141:q4*d1q1\$
(C134) a441:ev4az*drcq1+coe1*d4q1\$
(C135) a541:-ev5az*drcq1+coe*d5q1\$
(C136) ap1[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C137) a142:q4*d1q2\$
(C138) a442:ev4az*drcq2+coe1*d4q2\$
(C139) a542:-ev5az*drcq2+coe*d5q2\$
(C140) ap1[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C141) a143:q4*d1q3\$
(C142) a443:ev4az*drcq3+coe1*d4q3\$
(C143) a543:-ev5az*drcq3+coe*d5q3\$
(C144) ap1[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C145) a144:q4*d1q4+ev1\$
(C146) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C147) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C148) ap1[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C149) a145:q4*d1q5\$
(C150) a445:ev4az*drcq5+coe1*d4q5\$
(C151) a545:-ev5az*drcq5+coe*d5q5\$

(C152) ap1[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C153) rctt:rc*tt\$\n
(C154) coe:0.5*(q2**2+q3**2+q4**2)*q6\$\n
(C155) rt:rc*dttq1+tt*drcq1\$\n
(C156) a151:2*coe*d1q1\$\n
(C157) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$\n
(C158) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$\n
(C159) ap1[5,1]:cg1*a151+cg2*a451+cg3*a551\$\n
(C160) rt:rc*dttq2+tt*drcq2\$\n
(C161) a152:coe*d1q2-d1q1*q2\$\n
(C162) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$\n
(C163) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$\n
(C164) ap1[5,2]:cg1*a152+cg2*a452+cg3*a552\$\n
(C165) rt:rc*dttq3+tt*drcq3\$\n
(C166) a153:coe*d1q3-d1q1*q3\$\n
(C167) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$\n
(C168) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$\n
(C169) ap1[5,3]:cg1*a153+cg2*a453+cg3*a553\$\n
(C170) rt:rc*dttq4+tt*drcq4\$\n
(C171) a154:coe*d1q4-d1q1*q4\$\n
(C172) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$\n
(C173) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$\n
(C174) ap1[5,4]:cg1*a154+cg2*a454+cg3*a554\$\n
(C175) rt:tt*drcq5\$\n
(C176) a155:coe*d1q5\$\n
(C177) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$\n
(C178) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$\n
(C179) ap1[5,5]:cg1*a155+cg2*a455+cg3*a555\$\n
(C180) q1:q1\$\n
(C181) q2:q2\$\n
(C182) q3:q3\$\n
(C183) q4:-q4\$\n
(C184) q5:q5\$\n
(C185) sign:1\$\n
(C186) cggi:(gam-1)/gam\$\n
(C187) cgg2:1/(2*gam)\$\n
(C188) sada:sqrt(xix**2+xiy**2+xiz**2)\$\n
(C189) axt:xix/sada\$\n
(C190) ayt:xiy/sada\$\n
(C191) azt:xiz/sada\$\n
(C192) rqrq:q2**2+q3**2+q4**2\$\n
(C193) q6:1/q1\$\n
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$\n
(C195) prgam:pr*gam\$\n
(C196) pp:q5+pr\$\n
(C197) c:sqrt(prgam*q6)\$\n
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$\n
(C199) rc:q1*c\$\n
(C200) csad:c*sada\$\n
(C201) e1:tt*sada\$\n
(C202) e4:e1+csad\$

```

(C203) e5:e1-csad$
(C204) ev1:0.5*(e1+sign*abs(e1))$
(C205) ev4:0.5*(e4+sign*abs(e4))$
(C206) ev5:0.0$
(C207) cg1:cgg1$
(C208) cg2:cgg2$
(C209) cg3:0.0$
(C210) d1q1:-ev1*q6$
(C211) d1q2:xix*q6$
(C212) d1q3:xiy*q6$
(C213) d1q4:xiz*q6$
(C214) d1q5:0.0$
(C215) coe:gam*(gam-1)/(2*rc)$
(C216) gm1q6:(gam-1)*q6$
(C217) drcq1:coe*q5$
(C218) drcq2:-coe*q2$
(C219) drcq3:-coe*q3$
(C220) drcq4:-coe*q4$
(C221) drcq5:coe*q1$
(C222) dcq1:(drcq1-c)*q6$
(C223) dcq2:drcq2*q6$
(C224) dcq3:drcq3*q6$
(C225) dcq4:drcq4*q6$
(C226) dcq5:drcq5*q6$
(C227) depq1:0.5*gm1q6*rqrq*q6$
(C228) depq2:-q2*gm1q6$
(C229) depq3:-q3*gm1q6$
(C230) depq4:-q4*gm1q6$
(C231) depq5:gam$
(C232) dttq1:-tt*q6$
(C233) dttq2:axt*q6$
(C234) dttq3:ayt*q6$
(C235) dttq4:azt*q6$
(C236) dttq5:0.0$
(C237) d4q1:sada*(dttq1+dcq1)$
(C238) d4q2:sada*(dttq2+dcq2)$
(C239) d4q3:sada*(dttq3+dcq3)$
(C240) d4q4:sada*(dttq4+dcq4)$
(C241) d4q5:sada*dcq5$
(C242) d5q1:sada*(dttq1-dcq1)$
(C243) d5q2:sada*(dttq2-dcq2)$
(C244) d5q3:sada*(dttq3-dcq3)$
(C245) d5q4:sada*(dttq4-dcq4)$
(C246) d5q5:-d4q5$
(C247) a411:ev4+q1*d4q1$
(C248) a511:ev5+q1*d5q1$
(C249) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0])$
(C250) ap2[1,1]:cg2*a411+cg3*a511$
(C251) ap2[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C252) ap2[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$

```

(C253) ap2[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C254) ap2[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C255) rcaxt:rc*axt\$
(C256) ev4ax:ev4*axt\$
(C257) ev5ax:ev5*axt\$
(C258) coe1:q2+rcaxt\$
(C259) coe:q2-rcaxt\$
(C260) a121:q2*d1q1\$
(C261) a421:ev4ax*drcq1+coe1*d4q1\$
(C262) a521:-ev5ax*drcq1+coe*d5q1\$
(C263) ap2[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C264) a122:q2*d1q2+ev1\$
(C265) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C266) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C267) ap2[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C268) a123:q2*d1q3\$
(C269) a423:ev4ax*drcq3+coe1*d4q3\$
(C270) a523:-ev5ax*drcq3+coe*d5q3\$
(C271) ap2[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C272) a124:q2*d1q4\$
(C273) a424:ev4ax*drcq4+coe1*d4q4\$
(C274) a524:-ev5ax*drcq4+coe*d5q4\$
(C275) ap2[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C276) a125:q2*d1q5\$
(C277) a425:ev4ax*drcq5+coe1*d4q5\$
(C278) a525:-ev5ax*drcq5+coe*d5q5\$
(C279) ap2[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C280) rcayt:rc*ayt\$
(C281) ev4ay:ev4*ayt\$
(C282) ev5ay:ev5*ayt\$
(C283) coe1:q3+rcayt\$
(C284) coe:q3-rcayt\$
(C285) a131:q3*d1q1\$
(C286) a431:ev4ay*drcq1+coe1*d4q1\$
(C287) a531:-ev5ay*drcq1+coe*d5q1\$
(C288) ap2[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C289) a132:q3*d1q2\$
(C290) a432:ev4ay*drcq2+coe1*d4q2\$
(C291) a532:-ev5ay*drcq2+coe*d5q2\$
(C292) ap2[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C293) a133:q3*d1q3+ev1\$
(C294) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C295) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C296) ap2[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C297) a134:q3*d1q4\$
(C298) a434:ev4ay*drcq4+coe1*d4q4\$
(C299) a534:-ev5ay*drcq4+coe*d5q4\$
(C300) ap2[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C301) a135:q3*d1q5\$
(C302) a435:ev4ay*drcq5+coe1*d4q5\$
(C303) a535:-ev5ay*drcq5+coe*d5q5\$

(C304) ap2[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C305) rcazt:rc*azt\$
(C306) ev4az:ev4*azt\$
(C307) ev5az:ev5*azt\$
(C308) coe1:q4+rcazt\$
(C309) coe:q4-rcazt\$
(C310) a141:q4*d1q1\$
(C311) a441:ev4az*drcq1+coe1*d4q1\$
(C312) a541:-ev5az*drcq1+coe*d5q1\$
(C313) ap2[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C314) a142:q4*d1q2\$
(C315) a442:ev4az*drcq2+coe1*d4q2\$
(C316) a542:-ev5az*drcq2+coe*d5q2\$
(C317) ap2[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C318) a143:q4*d1q3\$
(C319) a443:ev4az*drcq3+coe1*d4q3\$
(C320) a543:-ev5az*drcq3+coe*d5q3\$
(C321) ap2[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C322) a144:q4*d1q4+ev1\$
(C323) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C324) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C325) ap2[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C326) a145:q4*d1q5\$
(C327) a445:ev4az*drcq5+coe1*d4q5\$
(C328) a545:-ev5az*drcq5+coe*d5q5\$
(C329) ap2[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C330) rctt:rc*tt\$
(C331) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C332) rt:rc*dttq1+tt*drcq1\$
(C333) a151:2*coe*d1q1\$
(C334) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C335) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C336) ap2[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C337) rt:rc*dttq2+tt*drcq2\$
(C338) a152:coe*d1q2-d1q1*q2\$
(C339) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C340) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C341) ap2[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C342) rt:rc*dttq3+tt*drcq3\$
(C343) a153:coe*d1q3-d1q1*q3\$
(C344) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C345) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C346) ap2[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C347) rt:rc*dttq4+tt*drcq4\$
(C348) a154:coe*d1q4-d1q1*q4\$
(C349) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C350) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C351) ap2[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C352) rt:tt*drcq5\$
(C353) a155:coe*d1q5\$
(C354) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$

APSUB

```
(C355) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5$  
(C356) ap2[5,5]:cg1*a155+cg2*a455+cg3*a555$  
(C357) diff:ap1.m-m.ap2$  
(C358) diff:ratexpand(diff);  
          [ 0 0 0 0 0 ]  
          [ ]  
          [ 0 0 0 0 0 ]  
          [ ]  
(D358)          [ 0 0 0 0 0 ]  
          [ ]  
          [ 0 0 0 0 0 ]  
          [ ]  
          [ 0 0 0 0 0 ]  
          [ ]  
(C359) closefile(Apsub)$  
***
```

```

(C3) ap1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,0,1])$
(C6) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C7) sign:1$
(C8) cgg1:(gam-1)/gam$
(C9) cgg2:1/(2*gam)$
(C10) xiy:0.0$
(C11) xiz:0.0$
(C12) sada:sqrt(xix**2+xiy**2+xiz**2)$
(C13) axt:xix/sada$
(C14) ayt:xiy/sada$
(C15) azt:xiz/sada$
(C16) rqrq:q2**2+q3**2+q4**2$
(C17) q6:1/q1$
(C18) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C19) prgam:pr*gam$
(C20) pp:q5+pr$
(C21) c:sqrt(prgam*q6)$
(C22) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C23) rc:q1*c$
(C24) csad:c*sada$
(C25) e1:tt*sada$
(C26) e4:e1+csad$
(C27) e5:e1-csad$
(C28) ev1:0.5*(e1+sign*abs(e1))$
(C29) ev4:0.5*(e4+sign*abs(e4))$
(C30) ev5:0.0$
(C31) cg1:cgg1$
(C32) cg2:cgg2$
(C33) cg3:0.0$
(C34) d1q1:-ev1*q6$
(C35) d1q2:xix*q6$
(C36) d1q3:xiy*q6$
(C37) d1q4:xiz*q6$
(C38) d1q5:0.0$
(C39) coe:gam*(gam-1)/(2*rc)$
(C40) gmlq6:(gam-1)*q6$
(C41) drcq1:coe*q5$
(C42) drcq2:-coe*q2$
(C43) drcq3:-coe*q3$
(C44) drcq4:-coe*q4$
(C45) drcq5:coe*q1$
(C46) dcq1:(drcq1-c)*q6$
(C47) dcq2:drcq2*q6$
(C48) dcq3:drcq3*q6$
(C49) dcq4:drcq4*q6$

```

(C50) dcq5:drcq5*q6\$
(C51) depq1:0.5*gmlq6*rqrq*q6\$
(C52) depq2:-q2*gmlq6\$
(C53) depq3:-q3*gmlq6\$
(C54) depq4:-q4*gmlq6\$
(C55) depq5:gam\$
(C56) dttq1:-tt*q6\$
(C57) dttq2:axt*q6\$
(C58) dttq3:ayt*q6\$
(C59) dttq4:azt*q6\$
(C60) dttq5:0.0\$
(C61) d4q1:sada*(dttq1+dcq1)\$
(C62) d4q2:sada*(dttq2+dcq2)\$
(C63) d4q3:sada*(dttq3+dcq3)\$
(C64) d4q4:sada*(dttq4+dcq4)\$
(C65) d4q5:sada*dcq5\$
(C66) d5q1:sada*(dttq1-dcq1)\$
(C67) d5q2:sada*(dttq2-dcq2)\$
(C68) d5q3:sada*(dttq3-dcq3)\$
(C69) d5q4:sada*(dttq4-dcq4)\$
(C70) d5q5:-d4q5\$
(C71) a411:ev4+q1*d4q1\$
(C72) a511:ev5+q1*d5q1\$
(C73) ap1[1,1]:cg2*a411+cg3*a511\$
(C74) ap1[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C75) ap1[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C76) ap1[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C77) ap1[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C78) rcaxt:rc*axt\$
(C79) ev4ax:ev4*axt\$
(C80) ev5ax:ev5*axt\$
(C81) coe1:q2+rcaxt\$
(C82) coe:q2-rcaxt\$
(C83) a121:q2*d1q1\$
(C84) a421:ev4ax*drcq1+coe1*d4q1\$
(C85) a521:-ev5ax*drcq1+coe*d5q1\$
(C86) ap1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C87) a122:q2*d1q2+ev1\$
(C88) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C89) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C90) ap1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C91) a123:q2*d1q3\$
(C92) a423:ev4ax*drcq3+coe1*d4q3\$
(C93) a523:-ev5ax*drcq3+coe*d5q3\$
(C94) ap1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C95) a124:q2*d1q4\$
(C96) a424:ev4ax*drcq4+coe1*d4q4\$
(C97) a524:-ev5ax*drcq4+coe*d5q4\$
(C98) ap1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C99) a125:q2*d1q5\$
(C100) a425:ev4ax*drcq5+coe1*d4q5\$

(C101) a525:-ev5ax*drcq5+coe*d5q5\$
(C102) ap1[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C103) rcayt:rc*ayt\$
(C104) ev4ay:ev4*ayt\$
(C105) ev5ay:ev5*ayt\$
(C106) coe1:q3+rcayt\$
(C107) coe:q3-rcayt\$
(C108) a131:q3*d1q1\$
(C109) a431:ev4ay*drcq1+coe1*d4q1\$
(C110) a531:-ev5ay*drcq1+coe*d5q1\$
(C111) ap1[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C112) a132:q3*d1q2\$
(C113) a432:ev4ay*drcq2+coe1*d4q2\$
(C114) a532:-ev5ay*drcq2+coe*d5q2\$
(C115) ap1[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C116) a133:q3*d1q3+ev1\$
(C117) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C118) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C119) ap1[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C120) a134:q3*d1q4\$
(C121) a434:ev4ay*drcq4+coe1*d4q4\$
(C122) a534:-ev5ay*drcq4+coe*d5q4\$
(C123) ap1[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C124) a135:q3*d1q5\$
(C125) a435:ev4ay*drcq5+coe1*d4q5\$
(C126) a535:-ev5ay*drcq5+coe*d5q5\$
(C127) ap1[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C128) rcazt:rc*azt\$
(C129) ev4az:ev4*azt\$
(C130) ev5az:ev5*azt\$
(C131) coe1:q4+rcazt\$
(C132) coe:q4-rcazt\$
(C133) a141:q4*d1q1\$
(C134) a441:ev4az*drcq1+coe1*d4q1\$
(C135) a541:-ev5az*drcq1+coe*d5q1\$
(C136) ap1[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C137) a142:q4*d1q2\$
(C138) a442:ev4az*drcq2+coe1*d4q2\$
(C139) a542:-ev5az*drcq2+coe*d5q2\$
(C140) ap1[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C141) a143:q4*d1q3\$
(C142) a443:ev4az*drcq3+coe1*d4q3\$
(C143) a543:-ev5az*drcq3+coe*d5q3\$
(C144) ap1[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C145) a144:q4*d1q4+ev1\$
(C146) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C147) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C148) ap1[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C149) a145:q4*d1q5\$
(C150) a445:ev4az*drcq5+coe1*d4q5\$
(C151) a545:-ev5az*drcq5+coe*d5q5\$

```

(C152) ap1[4,5]:cg1*a145+cg2*a445+cg3*a545$
(C153) rctt:rc*tt$
(C154) coe:0.5*(q2**2+q3**2+q4**2)*q6$
(C155) rt:rc*dttq1+tt*drcq1$
(C156) a151:2*coe*d1q1$
(C157) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1$
(C158) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1$
(C159) ap1[5,1]:cg1*a151+cg2*a451+cg3*a551$
(C160) rt:rc*dttq2+tt*drcq2$
(C161) a152:coe*d1q2-d1q1*q2$
(C162) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2$
(C163) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2$
(C164) ap1[5,2]:cg1*a152+cg2*a452+cg3*a552$
(C165) rt:rc*dttq3+tt*drcq3$
(C166) a153:coe*d1q3-d1q1*q3$
(C167) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3$
(C168) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3$
(C169) ap1[5,3]:cg1*a153+cg2*a453+cg3*a553$
(C170) rt:rc*dttq4+tt*drcq4$
(C171) a154:coe*d1q4-d1q1*q4$
(C172) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4$
(C173) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4$
(C174) ap1[5,4]:cg1*a154+cg2*a454+cg3*a554$
(C175) rt:tt*drcq5$
(C176) a155:coe*d1q5$
(C177) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5$
(C178) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5$
(C179) ap1[5,5]:cg1*a155+cg2*a455+cg3*a555$
(C180) q1:q1$
(C181) q2:q2$
(C182) q3:q3$
(C183) q4:-q4$
(C184) q5:q5$
(C185) sign:1$
(C186) cgg1:(gam-1)/gam$
(C187) cgg2:1/(2*gam)$
(C188) sada:sqrt(xix**2+xiy**2+xiz**2)$
(C189) axt:xix/sada$
(C190) ayt:xiy/sada$
(C191) azt:xiz/sada$
(C192) rqrq:q2**2+q3**2+q4**2$
(C193) q6:1/q1$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C195) prgam:pr*gam$
(C196) pp:q5+pr$
(C197) c:sqrt(prgam*q6)$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C199) rc:q1*c$
(C200) csad:c*sada$
(C201) e1:tt*sada$
(C202) e4:e1+csad$

```

```

(C203) e5:e1-csad$
(C204) ev1:0.5*(e1+sign*abs(e1))$
(C205) ev4:0.5*(e4+sign*abs(e4))$
(C206) ev5:0.0$
(C207) cg1:cgg1$
(C208) cg2:cgg2$
(C209) cg3:0.0$
(C210) d1q1:-ev1*q6$
(C211) d1q2:xix*q6$
(C212) d1q3:xiy*q6$
(C213) d1q4:xiz*q6$
(C214) d1q5:0.0$
(C215) coe:gam*(gam-1)/(2*rc)$
(C216) gm1q6:(gam-1)*q6$
(C217) drcq1:coe*q5$
(C218) drcq2:-coe*q2$
(C219) drcq3:-coe*q3$
(C220) drcq4:-coe*q4$
(C221) drcq5:coe*q1$
(C222) dcq1:(drcq1-c)*q6$
(C223) dcq2:drcq2*q6$
(C224) dcq3:drcq3*q6$
(C225) dcq4:drcq4*q6$
(C226) dcq5:drcq5*q6$
(C227) depq1:0.5*gm1q6*rqrq*q6$
(C228) depq2:-q2*gm1q6$
(C229) depq3:-q3*gm1q6$
(C230) depq4:-q4*gm1q6$
(C231) depq5:gam$
(C232) dttq1:-tt*q6$
(C233) dttq2:axt*q6$
(C234) dttq3:ayt*q6$
(C235) dttq4:azt*q6$
(C236) dttq5:0.0$
(C237) d4q1:sada*(dttq1+dcq1)$
(C238) d4q2:sada*(dttq2+dcq2)$
(C239) d4q3:sada*(dttq3+dcq3)$
(C240) d4q4:sada*(dttq4+dcq4)$
(C241) d4q5:sada*dcq5$
(C242) d5q1:sada*(dttq1-dcq1)$
(C243) d5q2:sada*(dttq2-dcq2)$
(C244) d5q3:sada*(dttq3-dcq3)$
(C245) d5q4:sada*(dttq4-dcq4)$
(C246) d5q5:-d4q5$
(C247) a411:ev4+q1*d4q1$
(C248) a511:ev5+q1*d5q1$
(C249) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],
[0,0,0,0,0])$
(C250) ap2[1,1]:cg2*a411+cg3*a511$
(C251) ap2[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C252) ap2[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$

```

(C253) ap2[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C254) ap2[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C255) rcaxt:rc*axt\$
(C256) ev4ax:ev4*axt\$
(C257) ev5ax:ev5*axt\$
(C258) coe1:q2+rcaxt\$
(C259) coe:q2-rcaxt\$
(C260) a121:q2*d1q1\$
(C261) a421:ev4ax*drcq1+coe1*d4q1\$
(C262) a521:-ev5ax*drcq1+coe*d5q1\$
(C263) ap2[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C264) a122:q2*d1q2+ev1\$
(C265) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C266) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C267) ap2[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C268) a123:q2*d1q3\$
(C269) a423:ev4ax*drcq3+coe1*d4q3\$
(C270) a523:-ev5ax*drcq3+coe*d5q3\$
(C271) ap2[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C272) a124:q2*d1q4\$
(C273) a424:ev4ax*drcq4+coe1*d4q4\$
(C274) a524:-ev5ax*drcq4+coe*d5q4\$
(C275) ap2[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C276) a125:q2*d1q5\$
(C277) a425:ev4ax*drcq5+coe1*d4q5\$
(C278) a525:-ev5ax*drcq5+coe*d5q5\$
(C279) ap2[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C280) rcayt:rc*ayt\$
(C281) ev4ay:ev4*ayt\$
(C282) ev5ay:ev5*ayt\$
(C283) coe1:q3+rcayt\$
(C284) coe:q3-rcayt\$
(C285) a131:q3*d1q1\$
(C286) a431:ev4ay*drcq1+coe1*d4q1\$
(C287) a531:-ev5ay*drcq1+coe*d5q1\$
(C288) ap2[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C289) a132:q3*d1q2\$
(C290) a432:ev4ay*drcq2+coe1*d4q2\$
(C291) a532:-ev5ay*drcq2+coe*d5q2\$
(C292) ap2[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C293) a133:q3*d1q3+ev1\$
(C294) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C295) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C296) ap2[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C297) a134:q3*d1q4\$
(C298) a434:ev4ay*drcq4+coe1*d4q4\$
(C299) a534:-ev5ay*drcq4+coe*d5q4\$
(C300) ap2[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C301) a135:q3*d1q5\$
(C302) a435:ev4ay*drcq5+coe1*d4q5\$
(C303) a535:-ev5ay*drcq5+coe*d5q5\$

(C304) ap2[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C305) rcazt:rc*azt\$
(C306) ev4az:ev4*azt\$
(C307) ev5az:ev5*azt\$
(C308) coe1:q4+rcazt\$
(C309) coe:q4-rcazt\$
(C310) a141:q4*d1q1\$
(C311) a441:ev4az*drcq1+coe1*d4q1\$
(C312) a541:-ev5az*drcq1+coe*d5q1\$
(C313) ap2[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C314) a142:q4*d1q2\$
(C315) a442:ev4az*drcq2+coe1*d4q2\$
(C316) a542:-ev5az*drcq2+coe*d5q2\$
(C317) ap2[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C318) a143:q4*d1q3\$
(C319) a443:ev4az*drcq3+coe1*d4q3\$
(C320) a543:-ev5az*drcq3+coe*d5q3\$
(C321) ap2[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C322) a144:q4*d1q4+ev1\$
(C323) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C324) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C325) ap2[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C326) a145:q4*d1q5\$
(C327) a445:ev4az*drcq5+coe1*d4q5\$
(C328) a545:-ev5az*drcq5+coe*d5q5\$
(C329) ap2[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C330) rctt:rc*tt\$
(C331) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C332) rt:rc*dttq1+tt*drcq1\$
(C333) a151:2*coe*d1q1\$
(C334) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C335) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C336) ap2[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C337) rt:rc*dttq2+tt*drcq2\$
(C338) a152:coe*d1q2-d1q1*q2\$
(C339) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C340) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C341) ap2[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C342) rt:rc*dttq3+tt*drcq3\$
(C343) a153:coe*d1q3-d1q1*q3\$
(C344) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C345) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C346) ap2[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C347) rt:rc*dttq4+tt*drcq4\$
(C348) a154:coe*d1q4-d1q1*q4\$
(C349) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C350) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C351) ap2[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C352) rt:tt*drcq5\$
(C353) a155:coe*d1q5\$
(C354) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$

APSUB

```
(C355) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5$  
(C356) ap2[5,5]:cg1*a155+cg2*a455+cg3*a555$  
(C357) diff:ap1.m-m.ap2$  
(C358) diff:ratexpand(diff);  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
(D358)  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
[ 0 0 0 0 0 ]  
  
(C359) closefile(Apsub)$  
***
```

```

(C3) am1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) am2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,0,1])$
(C6) sign:-1$ 
(C7) cg1:(gam-1)/gam$ 
(C8) cg2:1/(2*gam)$ 
(C9) xiy:0.0$ 
(C10) xiz:0.0$ 
(C11) sada:sqrt(xix**2+xiy**2+xiz**2)$ 
(C12) axt:xix/sada$ 
(C13) ayt:xiy/sada$ 
(C14) azt:xiz/sada$ 
(C15) rqrq:q2**2+q3**2+q4**2$ 
(C16) q6:1/q1$ 
(C17) pr:(gam-1)*(q5-0.5*rqrq*q6)$ 
(C18) prgam:pr*gam$ 
(C19) pp:q5+pr$ 
(C20) c:sqrt(prgam*q6)$ 
(C21) tt:(q2*axt+q3*ayt+q4*azt)*q6$ 
(C22) rc:q1*c$ 
(C23) csad:c*sada$ 
(C24) e1:tt*sada$ 
(C25) e4:e1+csad$ 
(C26) e5:e1-csad$ 
(C27) ev1:0.0$ 
(C28) ev4:0.0$ 
(C29) ev5:0.0$ 
(C30) cg1:0.0$ 
(C31) cg2:0.0$ 
(C32) cg3:0.0$ 
(C33) d1q1:-ev1*q6$ 
(C34) d1q2:xix*q6$ 
(C35) d1q3:xiy*q6$ 
(C36) d1q4:xiz*q6$ 
(C37) d1q5:0.0$ 
(C38) coe:gam*(gam-1)/(2*rc)$ 
(C39) gm1q6:(gam-1)*q6$ 
(C40) drcq1:coe*q5$ 
(C41) drcq2:-coe*q2$ 
(C42) drcq3:-coe*q3$ 
(C43) drcq4:-coe*q4$ 
(C44) drcq5:coe*q1$ 
(C45) dcq1:(drcq1-c)*q6$ 
(C46) dcq2:drcq2*q6$ 
(C47) dcq3:drcq3*q6$ 
(C48) dcq4:drcq4*q6$ 
(C49) dcq5:drcq5*q6$ 
(C50) depq1:0.5*gm1q6*rqrq*q6$ 

```

(C51) depq2:-q2*gmtq6\$
(C52) depq3:-q3*gmtq6\$
(C53) depq4:-q4*gmtq6\$
(C54) depq5:gam\$
(C55) dttq1:-tt*q6\$
(C56) dttq2:axt*q6\$
(C57) dttq3:ayt*q6\$
(C58) dttq4:azt*q6\$
(C59) dttq5:0.0\$
(C60) d4q1:sada*(dttq1+dcq1)\$
(C61) d4q2:sada*(dttq2+dcq2)\$
(C62) d4q3:sada*(dttq3+dcq3)\$
(C63) d4q4:sada*(dttq4+dcq4)\$
(C64) d4q5:sada*dcq5\$
(C65) d5q1:sada*(dttq1-dcq1)\$
(C66) d5q2:sada*(dttq2-dcq2)\$
(C67) d5q3:sada*(dttq3-dcq3)\$
(C68) d5q4:sada*(dttq4-dcq4)\$
(C69) d5q5:-d4q5\$
(C70) a411:ev4+q1*d4q1\$
(C71) a511:ev5+q1*d5q1\$
(C72) am1[1,1]:cg2*a411+cg3*a511\$
(C73) am1[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C74) am1[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C75) am1[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C76) am1[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C77) rcaxt:rc*axt\$
(C78) ev4ax:ev4*axt\$
(C79) ev5ax:ev5*axt\$
(C80) coe1:q2+rcaxt\$
(C81) coe:q2-rcaxt\$
(C82) a121:q2*d1q1\$
(C83) a421:ev4ax*drcq1+coe1*d4q1\$
(C84) a521:-ev5ax*drcq1+coe*d5q1\$
(C85) am1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C86) a122:q2*d1q2+ev1\$
(C87) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C88) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C89) am1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C90) a123:q2*d1q3\$
(C91) a423:ev4ax*drcq3+coe1*d4q3\$
(C92) a523:-ev5ax*drcq3+coe*d5q3\$
(C93) am1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C94) a124:q2*d1q4\$
(C95) a424:ev4ax*drcq4+coe1*d4q4\$
(C96) a524:-ev5ax*drcq4+coe*d5q4\$
(C97) am1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C98) a125:q2*d1q5\$
(C99) a425:ev4ax*drcq5+coe1*d4q5\$
(C100) a525:-ev5ax*drcq5+coe*d5q5\$
(C101) am1[2,5]:cg1*a125+cg2*a425+cg3*a525\$

(C102) rcayt:rc*ayt\$
(C103) ev4ay:ev4*ayt\$
(C104) ev5ay:ev5*ayt\$
(C105) coe1:q3+rcayt\$
(C106) coe:q3-rcayt\$
(C107) a131:q3*d1q1\$
(C108) a431:ev4ay*drcq1+coe1*d4q1\$
(C109) a531:-ev5ay*drcq1+coe*d5q1\$
(C110) am1[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C111) a132:q3*d1q2\$
(C112) a432:ev4ay*drcq2+coe1*d4q2\$
(C113) a532:-ev5ay*drcq2+coe*d5q2\$
(C114) am1[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C115) a133:q3*d1q3+ev1\$
(C116) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C117) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C118) am1[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C119) a134:q3*d1q4\$
(C120) a434:ev4ay*drcq4+coe1*d4q4\$
(C121) a534:-ev5ay*drcq4+coe*d5q4\$
(C122) am1[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C123) a135:q3*d1q5\$
(C124) a435:ev4ay*drcq5+coe1*d4q5\$
(C125) a535:-ev5ay*drcq5+coe*d5q5\$
(C126) am1[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C127) rcazt:rc*azt\$
(C128) ev4az:ev4*azt\$
(C129) ev5az:ev5*azt\$
(C130) coe1:q4+rcazt\$
(C131) coe:q4-rcazt\$
(C132) a141:q4*d1q1\$
(C133) a441:ev4az*drcq1+coe1*d4q1\$
(C134) a541:-ev5az*drcq1+coe*d5q1\$
(C135) am1[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C136) a142:q4*d1q2\$
(C137) a442:ev4az*drcq2+coe1*d4q2\$
(C138) a542:-ev5az*drcq2+coe*d5q2\$
(C139) am1[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C140) a143:q4*d1q3\$
(C141) a443:ev4az*drcq3+coe1*d4q3\$
(C142) a543:-ev5az*drcq3+coe*d5q3\$
(C143) am1[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C144) a144:q4*d1q4+ev1\$
(C145) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C146) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C147) am1[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C148) a145:q4*d1q5\$
(C149) a445:ev4az*drcq5+coe1*d4q5\$
(C150) a545:-ev5az*drcq5+coe*d5q5\$
(C151) am1[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C152) rctt:rc*tts\$

(C153) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C154) rt:rc*dttq1+tt*drcq1\$
(C155) a151:2*coe*d1q1\$
(C156) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C157) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C158) am1[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C159) rt:rc*dttq2+tt*drcq2\$
(C160) a152:coe*d1q2-d1q1*q2\$
(C161) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C162) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C163) am1[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C164) rt:rc*dttq3+tt*drcq3\$
(C165) a153:coe*d1q3-d1q1*q3\$
(C166) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C167) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C168) am1[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C169) rt:rc*dttq4+tt*drcq4\$
(C170) a154:coe*d1q4-d1q1*q4\$
(C171) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C172) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C173) am1[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C174) rt:tt*drcq5\$
(C175) a155:coe*d1q5\$
(C176) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C177) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C178) am1[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C179) q1:q1\$
(C180) q2:q2\$
(C181) q3:q3\$
(C182) q4:-q4\$
(C183) q5:q5\$
(C184) sign:1\$
(C185) cgg1:(gam-1)/gam\$
(C186) cgg2:1/(2*gam)\$
(C187) sada:sqrt(xix**2+xiy**2+xiz**2)\$
(C188) axt:xix/sada\$
(C189) ayt:xiy/sada\$
(C190) azt:xiz/sada\$
(C191) rqrq:q2**2+q3**2+q4**2\$
(C192) q6:1/q1\$
(C193) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C194) prgam:pr*gam\$
(C195) pp:q5+pr\$
(C196) c:sqrt(prgam*q6)\$
(C197) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C198) rc:q1*c\$
(C199) csad:c*sada\$
(C200) e1:tt*sada\$
(C201) e4:e1+csad\$
(C202) e5:e1-csad\$
(C203) ev1:0.0\$

```

(C204) ev4:0.0$
(C205) ev5:0.0$
(C206) cg1:0.0$
(C207) cg2:0.0$
(C208) cg3:0.0$
(C209) d1q1:-ev1*q6$
(C210) d1q2:xix*q6$
(C211) d1q3:xiy*q6$
(C212) d1q4:xiz*q6$
(C213) d1q5:0.0$
(C214) coe:gam*(gam-1)/(2*rc)$
(C215) gm1q6:(gam-1)*q6$
(C216) drcq1:coe*q5$
(C217) drcq2:-coe*q2$
(C218) drcq3:-coe*q3$
(C219) drcq4:-coe*q4$
(C220) drcq5:coe*q1$
(C221) dcq1:(drcq1-c)*q6$
(C222) dcq2:drcq2*q6$
(C223) dcq3:drcq3*q6$
(C224) dcq4:drcq4*q6$
(C225) dcq5:drcq5*q6$
(C226) depq1:0.5*gm1q6*rqrq*q6$
(C227) depq2:-q2*gm1q6$
(C228) depq3:-q3*gm1q6$
(C229) depq4:-q4*gm1q6$
(C230) depq5:gam$
(C231) dttq1:-tt*q6$
(C232) dttq2:axt*q6$
(C233) dttq3:ayt*q6$
(C234) dttq4:azt*q6$
(C235) dttq5:0.0$
(C236) d4q1:sada*(dttq1+dcq1)$
(C237) d4q2:sada*(dttq2+dcq2)$
(C238) d4q3:sada*(dttq3+dcq3)$
(C239) d4q4:sada*(dttq4+dcq4)$
(C240) d4q5:sada*dcq5$
(C241) d5q1:sada*(dttq1-dcq1)$
(C242) d5q2:sada*(dttq2-dcq2)$
(C243) d5q3:sada*(dttq3-dcq3)$
(C244) d5q4:sada*(dttq4-dcq4)$
(C245) d5q5:-d4q5$
(C246) a411:ev4+q1*d4q1$
(C247) a511:ev5+q1*d5q1$
(C248) am2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],
[0,0,0,0,0])$
(C249) am2[1,1]:cg2*a411+cg3*a511$
(C250) am2[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C251) am2[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$
(C252) am2[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1$
(C253) am2[1,5]: (cg2*d4q5+cg3*d5q5)*q1$

```

(C254) rcaxt:rc*axt\$
(C255) ev4ax:ev4*axt\$
(C256) ev5ax:ev5*axt\$
(C257) coe1:q2+rcaxt\$
(C258) coe:q2-rcaxt\$
(C259) a121:q2*d1q1\$
(C260) a421:ev4ax*drcq1+coe1*d4q1\$
(C261) a521:-ev5ax*drcq1+coe*d5q1\$
(C262) am2[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C263) a122:q2*d1q2+ev1\$
(C264) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C265) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C266) am2[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C267) a123:q2*d1q3\$
(C268) a423:ev4ax*drcq3+coe1*d4q3\$
(C269) a523:-ev5ax*drcq3+coe*d5q3\$
(C270) am2[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C271) a124:q2*d1q4\$
(C272) a424:ev4ax*drcq4+coe1*d4q4\$
(C273) a524:-ev5ax*drcq4+coe*d5q4\$
(C274) am2[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C275) a125:q2*d1q5\$
(C276) a425:ev4ax*drcq5+coe1*d4q5\$
(C277) a525:-ev5ax*drcq5+coe*d5q5\$
(C278) am2[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C279) rcayt:rc*ayt\$
(C280) ev4ay:ev4*ayt\$
(C281) ev5ay:ev5*ayt\$
(C282) coe1:q3+rcayt\$
(C283) coe:q3-rcayt\$
(C284) a131:q3*d1q1\$
(C285) a431:ev4ay*drcq1+coe1*d4q1\$
(C286) a531:-ev5ay*drcq1+coe*d5q1\$
(C287) am2[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C288) a132:q3*d1q2\$
(C289) a432:ev4ay*drcq2+coe1*d4q2\$
(C290) a532:-ev5ay*drcq2+coe*d5q2\$
(C291) am2[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C292) a133:q3*d1q3+ev1\$
(C293) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C294) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C295) am2[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C296) a134:q3*d1q4\$
(C297) a434:ev4ay*drcq4+coe1*d4q4\$
(C298) a534:-ev5ay*drcq4+coe*d5q4\$
(C299) am2[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C300) a135:q3*d1q5\$
(C301) a435:ev4ay*drcq5+coe1*d4q5\$
(C302) a535:-ev5ay*drcq5+coe*d5q5\$
(C303) am2[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C304) rcazt:rc*azt\$

(C305) ev4az:ev4*azt\$
(C306) ev5az:ev5*azt\$
(C307) coe1:q4+rcazt\$
(C308) coe:q4-rcazt\$
(C309) a141:q4*d1q1\$
(C310) a441:ev4az*drcq1+coe1*d4q1\$
(C311) a541:-ev5az*drcq1+coe*d5q1\$
(C312) am2[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C313) a142:q4*d1q2\$
(C314) a442:ev4az*drcq2+coe1*d4q2\$
(C315) a542:-ev5az*drcq2+coe*d5q2\$
(C316) am2[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C317) a143:q4*d1q3\$
(C318) a443:ev4az*drcq3+coe1*d4q3\$
(C319) a543:-ev5az*drcq3+coe*d5q3\$
(C320) am2[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C321) a144:q4*d1q4+ev1\$
(C322) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C323) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C324) am2[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C325) a145:q4*d1q5\$
(C326) a445:ev4az*drcq5+coe1*d4q5\$
(C327) a545:-ev5az*drcq5+coe*d5q5\$
(C328) am2[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C329) rctt:rc*tt\$
(C330) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C331) rt:rc*dttq1+tt*drcq1\$
(C332) a151:2*coe*d1q1\$
(C333) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C334) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C335) am2[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C336) rt:rc*dttq2+tt*drcq2\$
(C337) a152:coe*d1q2-d1q1*q2\$
(C338) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C339) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C340) am2[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C341) rt:rc*dttq3+tt*drcq3\$
(C342) a153:coe*d1q3-d1q1*q3\$
(C343) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C344) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C345) am2[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C346) rt:rc*dttq4+tt*drcq4\$
(C347) a154:coe*d1q4-d1q1*q4\$
(C348) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C349) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C350) am2[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C351) rt:tt*drcq5\$
(C352) a155:coe*d1q5\$
(C353) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C354) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C355) am2[5,5]:cg1*a155+cg2*a455+cg3*a555\$

AMSUP

(C356) diff:aml.m-m.aml\$
(C357) diff:ratexpand(diff);
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
(D357) [0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
(C358) closefile(Amsup)\$
■

```

(C3) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C4) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,0,1])$
(C5) sign:1$
(C6) cgg1:(gam-1)/gam$
(C7) cgg2:1/(2*gam)$
(C8) xiy:0.0$
(C9) xiz:0.0$
(C10) sada:sqrt(xix**2+xiy**2+xiz**2)$
(C11) axt:xix/sada$
(C12) ayt:xiy/sada$
(C13) azt:xiz/sada$
(C14) rqrq:q2**2+q3**2+q4**2$
(C15) q6:1/q1$
(C16) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C17) prgam:pr*gam$
(C18) pp:q5+pr$
(C19) c:sqrt(prgam*q6)$
(C20) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C21) rc:q1*c$*
(C22) csad:c*sada$
(C23) e1:tt*sada$
(C24) e4:e1+csad$*
(C25) e5:e1-csad$*
(C26) ev1:0.0$
(C27) ev4:0.0$
(C28) ev5:0.5*(e5+sign*abs(e5))$
(C29) cg1:0.0$
(C30) cg2:0.0$
(C31) cg3:cgg2$*
(C32) d1q1:-ev1*q6$*
(C33) d1q2:xix*q6$*
(C34) d1q3:xiy*q6$*
(C35) d1q4:xiz*q6$*
(C36) d1q5:0.0$*
(C37) coe:gam*(gam-1)/(2*rc)$*
(C38) gmlq6:(gam-1)*q6$*
(C39) drcq1:coe*q5$*
(C40) drcq2:-coe*q2$*
(C41) drcq3:-coe*q3$*
(C42) drcq4:-coe*q4$*
(C43) drcq5:coe*q1$*
(C44) dcq1:(drcq1-c)*q6$*
(C45) dcq2:drcq2*q6$*
(C46) dcq3:drcq3*q6$*
(C47) dcq4:drcq4*q6$*
(C48) dcq5:drcq5*q6$*
(C49) depq1:0.5*gmlq6*rqrq*q6$*
(C50) depq2:-q2*gmlq6$*
(C51) depq3:-q3*gmlq6$*

```

```

(C52) depq4:-q4*gmlq6$
(C53) depq5:gam$
(C54) dttq1:-tt*q6$
(C55) dttq2:axt*q6$
(C56) dttq3:ayt*q6$
(C57) dttq4:azt*q6$
(C58) dttq5:0.0$
(C59) d4q1:sada*(dttq1+dcq1)$
(C60) d4q2:sada*(dttq2+dcq2)$
(C61) d4q3:sada*(dttq3+dcq3)$
(C62) d4q4:sada*(dttq4+dcq4)$
(C63) d4q5:sada*dcq5$
(C64) d5q1:sada*(dttq1-dcq1)$
(C65) d5q2:sada*(dttq2-dcq2)$
(C66) d5q3:sada*(dttq3-dcq3)$
(C67) d5q4:sada*(dttq4-dcq4)$
(C68) d5q5:-d4q5$
(C69) a411:ev4+q1*d4q1$
(C70) a511:ev5+q1*d5q1$
(C71) ap1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0])$ 
(C72) ap2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0])$ 
(C73) ap1[1,1]:cg2*a411+cg3*a511$
(C74) ap1[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C75) ap1[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$
(C76) ap1[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1$
(C77) ap1[1,5]: (cg2*d4q5+cg3*d5q5)*q1$
(C78) rcaxt:rc*axt$
(C79) ev4ax:ev4*axt$
(C80) ev5ax:ev5*axt$
(C81) coe1:q2+rcaxt$
(C82) coe:q2-rcaxt$
(C83) a121:q2*d1q1$
(C84) a421:ev4ax*drcq1+coe1*d4q1$
(C85) a521:-ev5ax*drcq1+coe*d5q1$
(C86) ap1[2,1]:cg1*a121+cg2*a421+cg3*a521$
(C87) a122:q2*d1q2+ev1$
(C88) a422:ev4+ev4ax*drcq2+coe1*d4q2$
(C89) a522:ev5-ev5ax*drcq2+coe*d5q2$
(C90) ap1[2,2]:cg1*a122+cg2*a422+cg3*a522$
(C91) a123:q2*d1q3$
(C92) a423:ev4ax*drcq3+coe1*d4q3$
(C93) a523:-ev5ax*drcq3+coe*d5q3$
(C94) ap1[2,3]:cg1*a123+cg2*a423+cg3*a523$
(C95) a124:q2*d1q4$
(C96) a424:ev4ax*drcq4+coe1*d4q4$
(C97) a524:-ev5ax*drcq4+coe*d5q4$
(C98) ap1[2,4]:cg1*a124+cg2*a424+cg3*a524$
(C99) a125:q2*d1q5$
(C100) a425:ev4ax*drcq5+coe1*d4q5$

```

(C101) a525:-ev5ax*drcq5+coe*d5q5\$
(C102) ap1[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C103) rcayt:rc*ayt\$
(C104) ev4ay:ev4*ayt\$
(C105) ev5ay:ev5*ayt\$
(C106) coe1:q3+rcayt\$
(C107) coe:q3-rcayt\$
(C108) a131:q3*d1q1\$
(C109) a431:ev4ay*drcq1+coe1*d4q1\$
(C110) a531:-ev5ay*drcq1+coe*d5q1\$
(C111) ap1[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C112) a132:q3*d1q2\$
(C113) a432:ev4ay*drcq2+coe1*d4q2\$
(C114) a532:-ev5ay*drcq2+coe*d5q2\$
(C115) ap1[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C116) a133:q3*d1q3+ev1\$
(C117) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C118) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C119) ap1[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C120) a134:q3*d1q4\$
(C121) a434:ev4ay*drcq4+coe1*d4q4\$
(C122) a534:-ev5ay*drcq4+coe*d5q4\$
(C123) ap1[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C124) a135:q3*d1q5\$
(C125) a435:ev4ay*drcq5+coe1*d4q5\$
(C126) a535:-ev5ay*drcq5+coe*d5q5\$
(C127) ap1[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C128) rcazt:rc*azt\$
(C129) ev4az:ev4*azt\$
(C130) ev5az:ev5*azt\$
(C131) coe1:q4+rcazt\$
(C132) coe:q4-rcazt\$
(C133) a141:q4*d1q1\$
(C134) a441:ev4az*drcq1+coe1*d4q1\$
(C135) a541:-ev5az*drcq1+coe*d5q1\$
(C136) ap1[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C137) a142:q4*d1q2\$
(C138) a442:ev4az*drcq2+coe1*d4q2\$
(C139) a542:-ev5az*drcq2+coe*d5q2\$
(C140) ap1[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C141) a143:q4*d1q3\$
(C142) a443:ev4az*drcq3+coe1*d4q3\$
(C143) a543:-ev5az*drcq3+coe*d5q3\$
(C144) ap1[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C145) a144:q4*d1q4+ev1\$
(C146) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C147) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C148) ap1[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C149) a145:q4*d1q5\$
(C150) a445:ev4az*drcq5+coe1*d4q5\$
(C151) a545:-ev5az*drcq5+coe*d5q5\$

```

(C152) ap1[4,5]:cg1*a145+cg2*a445+cg3*a545$
(C153) rctt:rc*tt$
(C154) coe:0.5*(q2**2+q3**2+q4**2)*q6$
(C155) rt:rc*dttq1+tt*drcq1$
(C156) a151:2*coe*d1q1$
(C157) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1$
(C158) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1$
(C159) ap1[5,1]:cg1*a151+cg2*a451+cg3*a551$
(C160) rt:rc*dttq2+tt*drcq2$
(C161) a152:coe*d1q2-d1q1*q2$
(C162) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2$
(C163) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2$
(C164) ap1[5,2]:cg1*a152+cg2*a452+cg3*a552$
(C165) rt:rc*dttq3+tt*drcq3$
(C166) a153:coe*d1q3-d1q1*q3$
(C167) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3$
(C168) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3$
(C169) ap1[5,3]:cg1*a153+cg2*a453+cg3*a553$
(C170) rt:rc*dttq4+tt*drcq4$
(C171) a154:coe*d1q4-d1q1*q4$
(C172) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4$
(C173) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4$
(C174) ap1[5,4]:cg1*a154+cg2*a454+cg3*a554$
(C175) rt:tt*drcq5$
(C176) a155:coe*d1q5$
(C177) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5$
(C178) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5$
(C179) ap1[5,5]:cg1*a155+cg2*a455+cg3*a555$
(C180) q1:q1$
(C181) q2:q2$
(C182) q3:q3$
(C183) q4:-q4$
(C184) q5:q5$
(C185) sign:1$
(C186) cggi:(gam-1)/gam$
(C187) cgg2:1/(2*gam)$
(C188) sada:sqrt(xix**2+xiy**2+xiz**2)$
(C189) axt:xix/sada$
(C190) ayt:xiy/sada$
(C191) azt:xiz/sada$
(C192) rqrq:q2**2+q3**2+q4**2$
(C193) q6:1/q1$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C195) prgam:pr*gam$
(C196) pp:q5+pr$
(C197) c:sqrt(prgam*q6)$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C199) rc:q1*c$
(C200) csad:c*sada$
(C201) e1:tt*sada$
(C202) e4:e1+csad$

```

```

(C203) e5:e1-csad$
(C204) ev1:0.0$
(C205) ev4:0.0$
(C206) ev5:0.5*(e5+sign*abs(e5))$
(C207) cg1:0.0$
(C208) cg2:0.0$
(C209) cg3:cgg2$
(C210) d1q1:-ev1*q6$
(C211) d1q2:xix*q6$
(C212) d1q3:xiy*q6$
(C213) d1q4:xiz*q6$
(C214) d1q5:0.0$
(C215) coe:gam*(gam-1)/(2*rc)$
(C216) gm1q6:(gam-1)*q6$
(C217) drcq1:coe*q5$
(C218) drcq2:-coe*q2$
(C219) drcq3:-coe*q3$
(C220) drcq4:-coe*q4$
(C221) drcq5:coe*q1$
(C222) dcq1:(drcq1-c)*q6$
(C223) dcq2:drcq2*q6$
(C224) dcq3:drcq3*q6$
(C225) dcq4:drcq4*q6$
(C226) dcq5:drcq5*q6$
(C227) depq1:0.5*gm1q6*rqrq*q6$
(C228) depq2:-q2*gm1q6$
(C229) depq3:-q3*gm1q6$
(C230) depq4:-q4*gm1q6$
(C231) depq5:gam$
(C232) dttq1:-tt*q6$
(C233) dttq2:axt*q6$
(C234) dttq3:ayt*q6$
(C235) dttq4:azt*q6$
(C236) dttq5:0.0$
(C237) d4q1:sada*(dttq1+dcq1)$
(C238) d4q2:sada*(dttq2+dcq2)$
(C239) d4q3:sada*(dttq3+dcq3)$
(C240) d4q4:sada*(dttq4+dcq4)$
(C241) d4q5:sada*dcq5$
(C242) d5q1:sada*(dttq1-dcq1)$
(C243) d5q2:sada*(dttq2-dcq2)$
(C244) d5q3:sada*(dttq3-dcq3)$
(C245) d5q4:sada*(dttq4-dcq4)$
(C246) d5q5:-d4q5$
(C247) a411:ev4+q1*d4q1$
(C248) a511:ev5+q1*d5q1$
(C249) ap2[1,1]:cg2*a411+cg3*a511$
(C250) ap2[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C251) ap2[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$
(C252) ap2[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1$
(C253) ap2[1,5]:(cg2*d4q5+cg3*d5q5)*q1$

```

(C254) rcaxt:rc*axt\$
(C255) ev4ax:ev4*axt\$
(C256) ev5ax:ev5*axt\$
(C257) coe1:q2+rcaxt\$
(C258) coe:q2-rcaxt\$
(C259) a121:q2*d1q1\$
(C260) a421:ev4ax*drcq1+coe1*d4q1\$
(C261) a521:-ev5ax*drcq1+coe*d5q1\$
(C262) ap2[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C263) a122:q2*d1q2+ev1\$
(C264) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C265) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C266) ap2[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C267) a123:q2*d1q3\$
(C268) a423:ev4ax*drcq3+coe1*d4q3\$
(C269) a523:-ev5ax*drcq3+coe*d5q3\$
(C270) ap2[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C271) a124:q2*d1q4\$
(C272) a424:ev4ax*drcq4+coe1*d4q4\$
(C273) a524:-ev5ax*drcq4+coe*d5q4\$
(C274) ap2[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C275) a125:q2*d1q5\$
(C276) a425:ev4ax*drcq5+coe1*d4q5\$
(C277) a525:-ev5ax*drcq5+coe*d5q5\$
(C278) ap2[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C279) rcayt:rc*ayt\$
(C280) ev4ay:ev4*ayt\$
(C281) ev5ay:ev5*ayt\$
(C282) coe1:q3+rcayt\$
(C283) coe:q3-rcayt\$
(C284) a131:q3*d1q1\$
(C285) a431:ev4ay*drcq1+coe1*d4q1\$
(C286) a531:-ev5ay*drcq1+coe*d5q1\$
(C287) ap2[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C288) a132:q3*d1q2\$
(C289) a432:ev4ay*drcq2+coe1*d4q2\$
(C290) a532:-ev5ay*drcq2+coe*d5q2\$
(C291) ap2[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C292) a133:q3*d1q3+ev1\$
(C293) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C294) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C295) ap2[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C296) a134:q3*d1q4\$
(C297) a434:ev4ay*drcq4+coe1*d4q4\$
(C298) a534:-ev5ay*drcq4+coe*d5q4\$
(C299) ap2[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C300) a135:q3*d1q5\$
(C301) a435:ev4ay*drcq5+coe1*d4q5\$
(C302) a535:-ev5ay*drcq5+coe*d5q5\$
(C303) ap2[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C304) rcazt:rc*azt\$

(C305) ev4az:ev4*azt\$
(C306) ev5az:ev5*azt\$
(C307) coe1:q4+rcazt\$
(C308) coe:q4-rcazt\$
(C309) a141:q4*d1q1\$
(C310) a441:ev4az*drcq1+coe1*d4q1\$
(C311) a541:-ev5az*drcq1+coe*d5q1\$
(C312) ap2[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C313) a142:q4*d1q2\$
(C314) a442:ev4az*drcq2+coe1*d4q2\$
(C315) a542:-ev5az*drcq2+coe*d5q2\$
(C316) ap2[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C317) a143:q4*d1q3\$
(C318) a443:ev4az*drcq3+coe1*d4q3\$
(C319) a543:-ev5az*drcq3+coe*d5q3\$
(C320) ap2[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C321) a144:q4*d1q4+ev1\$
(C322) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C323) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C324) ap2[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C325) a145:q4*d1q5\$
(C326) a445:ev4az*drcq5+coe1*d4q5\$
(C327) a545:-ev5az*drcq5+coe*d5q5\$
(C328) ap2[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C329) rctt:rc*tt\$
(C330) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C331) rt:rc*dttq1+tt*drcq1\$
(C332) a151:2*coe*d1q1\$
(C333) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C334) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C335) ap2[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C336) rt:rc*dttq2+tt*drcq2\$
(C337) a152:coe*d1q2-d1q1*q2\$
(C338) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C339) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C340) ap2[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C341) rt:rc*dttq3+tt*drcq3\$
(C342) a153:coe*d1q3-d1q1*q3\$
(C343) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C344) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C345) ap2[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C346) rt:rc*dttq4+tt*drcq4\$
(C347) a154:coe*d1q4-d1q1*q4\$
(C348) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C349) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C350) ap2[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C351) rt:tt*drcq5\$
(C352) a155:coe*d1q5\$
(C353) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C354) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C355) ap2[5,5]:cg1*a155+cg2*a455+cg3*a555\$

AMSUB

(C356) diff:ap1.m-m.ap2\$
(C357) diff:ratexpand(diff);

[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]

(D357)

(C358) closefile(Amsub)\$

```

(C3) bp1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) bp2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C6) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C7) sign:1$
(C8) cgg1:(gam-1)/gam$
(C9) cgg2:1/(2*gam)$
(C10) etx:0.0$
(C11) sada:sqrt(etx**2+ety**2+etz**2)$
(C12) axt:etx/sada$
(C13) ayt:ety/sada$
(C14) azt:etz/sada$
(C15) rqrq:q2**2+q3**2+q4**2$
(C16) q6:1/q1$
(C17) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C18) prgam:pr*gam$
(C19) pp:q5+pr$
(C20) c:sqrt(prgam*q6)$
(C21) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C22) rc:q1*c$
(C23) csad:c*sada$
(C24) e1:tt*sada$
(C25) e4:e1+csad$
(C26) e5:e1-csad$
(C27) ev1:0.5*(e1+sign*abs(e1))$
(C28) ev4:0.5*(e4+sign*abs(e4))$
(C29) ev5:0.5*(e5+sign*abs(e5))$
(C30) cg1:cgg1$
(C31) cg2:cgg2$
(C32) cg3:cgg2$
(C33) d1q1:-ev1*q6$
(C34) d1q2:etx*q6$
(C35) d1q3:ety*q6$
(C36) d1q4:etz*q6$
(C37) d1q5:0.0$
(C38) coe:gam*(gam-1)/(2*rc)$
(C39) gm1q6:(gam-1)*q6$
(C40) drcq1:coe*q5$
(C41) drcq2:-coe*q2$
(C42) drcq3:-coe*q3$
(C43) drcq4:-coe*q4$
(C44) drcq5:coe*q1$
(C45) dcq1:(drcq1-c)*q6$
(C46) dcq2:drcq2*q6$
(C47) dcq3:drcq3*q6$
(C48) dcq4:drcq4*q6$
(C49) dcq5:drcq5*q6$

```

(C50) depq1:0.5*gm1q6*rqrq*q6\$
(C51) depq2:-q2*gm1q6\$
(C52) depq3:-q3*gm1q6\$
(C53) depq4:-q4*gm1q6\$
(C54) depq5:gam\$
(C55) dttq1:-tt*q6\$
(C56) dttq2:axt*q6\$
(C57) dttq3:ayt*q6\$
(C58) dttq4:azt*q6\$
(C59) dttq5:0.0\$
(C60) d4q1:sada*(dttq1+dcq1)\$
(C61) d4q2:sada*(dttq2+dcq2)\$
(C62) d4q3:sada*(dttq3+dcq3)\$
(C63) d4q4:sada*(dttq4+dcq4)\$
(C64) d4q5:sada*dcq5\$
(C65) d5q1:sada*(dttq1-dcq1)\$
(C66) d5q2:sada*(dttq2-dcq2)\$
(C67) d5q3:sada*(dttq3-dcq3)\$
(C68) d5q4:sada*(dttq4-dcq4)\$
(C69) d5q5:-d4q5\$
(C70) a411:ev4+q1*d4q1\$
(C71) a511:ev5+q1*d5q1\$
(C72) bp1[1,1]:cg2*a411+cg3*a511\$
(C73) bp1[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C74) bp1[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C75) bp1[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C76) bp1[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C77) rcaxt:rc*axt\$
(C78) ev4ax:ev4*axt\$
(C79) ev5ax:ev5*axt\$
(C80) coe1:q2+rcaxt\$
(C81) coe:q2-rcaxt\$
(C82) a121:q2*d1q1\$
(C83) a421:ev4ax*drcq1+coe1*d4q1\$
(C84) a521:-ev5ax*drcq1+coe*d5q1\$
(C85) bp1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C86) a122:q2*d1q2+ev1\$
(C87) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C88) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C89) bp1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C90) a123:q2*d1q3\$
(C91) a423:ev4ax*drcq3+coe1*d4q3\$
(C92) a523:-ev5ax*drcq3+coe*d5q3\$
(C93) bp1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C94) a124:q2*d1q4\$
(C95) a424:ev4ax*drcq4+coe1*d4q4\$
(C96) a524:-ev5ax*drcq4+coe*d5q4\$
(C97) bp1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C98) a125:q2*d1q5\$
(C99) a425:ev4ax*drcq5+coe1*d4q5\$
(C100) a525:-ev5ax*drcq5+coe*d5q5\$

(C101) $bp1[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C102) $rcayt:rc*ayt\$$
(C103) $ev4ay:ev4*ayt\$$
(C104) $ev5ay:ev5*ayt\$$
(C105) $coe1:q3+rcayt\$$
(C106) $coe:q3-rcayt\$$
(C107) $a131:q3*d1q1\$$
(C108) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C109) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C110) $bp1[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C111) $a132:q3*d1q2\$$
(C112) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C113) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C114) $bp1[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C115) $a133:q3*d1q3+ev1\$$
(C116) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C117) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C118) $bp1[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C119) $a134:q3*d1q4\$$
(C120) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C121) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C122) $bp1[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C123) $a135:q3*d1q5\$$
(C124) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C125) $a535:-ev5ay*drcq5+coe*d5q5\$$
(C126) $bp1[3,5]:cg1*a135+cg2*a435+cg3*a535\$$
(C127) $rcazt:rc*azt\$$
(C128) $ev4az:ev4*azt\$$
(C129) $ev5az:ev5*azt\$$
(C130) $coe1:q4+rcazt\$$
(C131) $coe:q4-rcazt\$$
(C132) $a141:q4*d1q1\$$
(C133) $a441:ev4az*drcq1+coe1*d4q1\$$
(C134) $a541:-ev5az*drcq1+coe*d5q1\$$
(C135) $bp1[4,1]:cg1*a141+cg2*a441+cg3*a541\$$
(C136) $a142:q4*d1q2\$$
(C137) $a442:ev4az*drcq2+coe1*d4q2\$$
(C138) $a542:-ev5az*drcq2+coe*d5q2\$$
(C139) $bp1[4,2]:cg1*a142+cg2*a442+cg3*a542\$$
(C140) $a143:q4*d1q3\$$
(C141) $a443:ev4az*drcq3+coe1*d4q3\$$
(C142) $a543:-ev5az*drcq3+coe*d5q3\$$
(C143) $bp1[4,3]:cg1*a143+cg2*a443+cg3*a543\$$
(C144) $a144:q4*d1q4+ev1\$$
(C145) $a444:ev4+ev4az*drcq4+coe1*d4q4\$$
(C146) $a544:ev5-ev5az*drcq4+coe*d5q4\$$
(C147) $bp1[4,4]:cg1*a144+cg2*a444+cg3*a544\$$
(C148) $a145:q4*d1q5\$$
(C149) $a445:ev4az*drcq5+coe1*d4q5\$$
(C150) $a545:-ev5az*drcq5+coe*d5q5\$$
(C151) $bp1[4,5]:cg1*a145+cg2*a445+cg3*a545\$$

(C152) rctt:rc*tt\$
(C153) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C154) rt:rc*dttq1+tt*drcq1\$
(C155) a151:2*coe*d1q1\$
(C156) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C157) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C158) bp1[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C159) rt:rc*dttq2+tt*drcq2\$
(C160) a152:coe*d1q2-d1q1*q2\$
(C161) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C162) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C163) bp1[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C164) rt:rc*dttq3+tt*drcq3\$
(C165) a153:coe*d1q3-d1q1*q3\$
(C166) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C167) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C168) bp1[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C169) rt:rc*dttq4+tt*drcq4\$
(C170) a154:coe*d1q4-d1q1*q4\$
(C171) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C172) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C173) bp1[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C174) rt:tt*drcq5\$
(C175) a155:coe*d1q5\$
(C176) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C177) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C178) bp1[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C179) q1:q1\$
(C180) q2:q2\$
(C181) q3:q3\$
(C182) q4:-q4\$
(C183) q5:q5\$
(C184) sign:1\$
(C185) etz:-etz;
(C186) cgg1:(gam-1)/gam\$
(C187) cgg2:1/(2*gam)\$
(C188) sada:sqrt(etx**2+ety**2+etz**2)\$
(C189) axt:etx/sada\$
(C190) ayt:ety/sada\$
(C191) azt:etz/sada\$
(C192) rqrq:q2**2+q3**2+q4**2\$
(C193) q6:1/q1\$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C195) prgam:pr*gam\$
(C196) pp:q5+pr\$
(C197) c:sqrt(prgam*q6)\$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C199) rc:q1*c\$
(C200) csad:c*sada\$
(C201) e1:tt*sada\$
(C202) e4:e1+csad\$

```

(C203) e5:e1-csad$
(C204) ev1:0.5*(e1+sign*abs(e1))$
(C205) ev4:0.5*(e4+sign*abs(e4))$
(C206) ev5:0.5*(e5+sign*abs(e5))$
(C207) cg1:cgg1$
(C208) cg2:cgg2$
(C209) cg3:cgg2$
(C210) d1q1:-ev1*q6$
(C211) d1q2:etx*q6$
(C212) d1q3:ety*q6$
(C213) d1q4:etz*q6$
(C214) d1q5:0.0$
(C215) coe:gam*(gam-1)/(2*rc)$
(C216) gm1q6:(gam-1)*q6$
(C217) drcq1:coe*q5$
(C218) drcq2:-coe*q2$
(C219) drcq3:-coe*q3$
(C220) drcq4:-coe*q4$
(C221) drcq5:coe*q1$
(C222) dcq1:(drcq1-c)*q6$
(C223) dcq2:drcq2*q6$
(C224) dcq3:drcq3*q6$
(C225) dcq4:drcq4*q6$
(C226) dcq5:drcq5*q6$
(C227) depq1:0.5*gm1q6*rqrq*q6$
(C228) depq2:-q2*gm1q6$
(C229) depq3:-q3*gm1q6$
(C230) depq4:-q4*gm1q6$
(C231) depq5:gam$
(C232) dttq1:-tt*q6$
(C233) dttq2:axt*q6$
(C234) dttq3:ayt*q6$
(C235) dttq4:azt*q6$
(C236) dttq5:0.0$
(C237) d4q1:sada*(dttq1+dcq1)$
(C238) d4q2:sada*(dttq2+dcq2)$
(C239) d4q3:sada*(dttq3+dcq3)$
(C240) d4q4:sada*(dttq4+dcq4)$
(C241) d4q5:sada*dcq5$
(C242) d5q1:sada*(dttq1-dcq1)$
(C243) d5q2:sada*(dttq2-dcq2)$
(C244) d5q3:sada*(dttq3-dcq3)$
(C245) d5q4:sada*(dttq4-dcq4)$
(C246) d5q5:-d4q5$
(C247) a411:ev4+q1*d4q1$
(C248) a511:ev5+q1*d5q1$
(C249) bp2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0])$
(C250) bp2[1,1]:cg2*a411+cg3*a511$
(C251) bp2[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C252) bp2[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$

```

(C253) $bp2[1,4] : (cg1*d1q4 + cg2*d4q4 + cg3*d5q4) * q1\$$
(C254) $bp2[1,5] : (cg2*d4q5 + cg3*d5q5) * q1\$$
(C255) $rcaxt:rc*axt\$$
(C256) $ev4ax:ev4*axt\$$
(C257) $ev5ax:ev5*axt\$$
(C258) $coe1:q2+rcaxt\$$
(C259) $coe:q2-rcaxt\$$
(C260) $a121:q2*d1q1\$$
(C261) $a421:ev4ax*drcq1+coe1*d4q1\$$
(C262) $a521:-ev5ax*drcq1+coe*d5q1\$$
(C263) $bp2[2,1]:cg1*a121+cg2*a421+cg3*a521\$$
(C264) $a122:q2*d1q2+ev1\$$
(C265) $a422:ev4+ev4ax*drcq2+coe1*d4q2\$$
(C266) $a522:ev5-ev5ax*drcq2+coe*d5q2\$$
(C267) $bp2[2,2]:cg1*a122+cg2*a422+cg3*a522\$$
(C268) $a123:q2*d1q3\$$
(C269) $a423:ev4ax*drcq3+coe1*d4q3\$$
(C270) $a523:-ev5ax*drcq3+coe*d5q3\$$
(C271) $bp2[2,3]:cg1*a123+cg2*a423+cg3*a523\$$
(C272) $a124:q2*d1q4\$$
(C273) $a424:ev4ax*drcq4+coe1*d4q4\$$
(C274) $a524:-ev5ax*drcq4+coe*d5q4\$$
(C275) $bp2[2,4]:cg1*a124+cg2*a424+cg3*a524\$$
(C276) $a125:q2*d1q5\$$
(C277) $a425:ev4ax*drcq5+coe1*d4q5\$$
(C278) $a525:-ev5ax*drcq5+coe*d5q5\$$
(C279) $bp2[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C280) $rcayt:rc*ayt\$$
(C281) $ev4ay:ev4*ayt\$$
(C282) $ev5ay:ev5*ayt\$$
(C283) $coe1:q3+rcayt\$$
(C284) $coe:q3-rcayt\$$
(C285) $a131:q3*d1q1\$$
(C286) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C287) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C288) $bp2[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C289) $a132:q3*d1q2\$$
(C290) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C291) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C292) $bp2[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C293) $a133:q3*d1q3+ev1\$$
(C294) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C295) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C296) $bp2[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C297) $a134:q3*d1q4\$$
(C298) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C299) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C300) $bp2[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C301) $a135:q3*d1q5\$$
(C302) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C303) $a535:-ev5ay*drcq5+coe*d5q5\$$

(C304) $bp2[3,5]:cg1*a135+cg2*a435+cg3*a535$$
(C305) $rcazt:rc*azt$$
(C306) $ev4az:ev4*azt$$
(C307) $ev5az:ev5*azt$$
(C308) $coe1:q4+rcazt$$
(C309) $coe:q4-rcazt$$
(C310) $a141:q4*d1q1$$
(C311) $a441:ev4az*drcq1+coe1*d4q1$$
(C312) $a541:-ev5az*drcq1+coe*d5q1$$
(C313) $bp2[4,1]:cg1*a141+cg2*a441+cg3*a541$$
(C314) $a142:q4*d1q2$$
(C315) $a442:ev4az*drcq2+coe1*d4q2$$
(C316) $a542:-ev5az*drcq2+coe*d5q2$$
(C317) $bp2[4,2]:cg1*a142+cg2*a442+cg3*a542$$
(C318) $a143:q4*d1q3$$
(C319) $a443:ev4az*drcq3+coe1*d4q3$$
(C320) $a543:-ev5az*drcq3+coe*d5q3$$
(C321) $bp2[4,3]:cg1*a143+cg2*a443+cg3*a543$$
(C322) $a144:q4*d1q4+ev1$$
(C323) $a444:ev4+ev4az*drcq4+coe1*d4q4$$
(C324) $a544:ev5-ev5az*drcq4+coe*d5q4$$
(C325) $bp2[4,4]:cg1*a144+cg2*a444+cg3*a544$$
(C326) $a145:q4*d1q5$$
(C327) $a445:ev4az*drcq5+coe1*d4q5$$
(C328) $a545:-ev5az*drcq5+coe*d5q5$$
(C329) $bp2[4,5]:cg1*a145+cg2*a445+cg3*a545$$
(C330) $rctt:rc*tts$$
(C331) $coe:0.5*(q2**2+q3**2+q4**2)*q6$$
(C332) $rt:rc*dttq1+tt*drcq1$$
(C333) $a151:2*coe*d1q1$$
(C334) $a451:ev4*(depq1+rt)+(pp+rctt)*d4q1$$
(C335) $a551:ev5*(depq1-rt)+(pp-rctt)*d5q1$$
(C336) $bp2[5,1]:cg1*a151+cg2*a451+cg3*a551$$
(C337) $rt:rc*dttq2+tt*drcq2$$
(C338) $a152:coe*d1q2-d1q1*q2$$
(C339) $a452:ev4*(depq2+rt)+(pp+rctt)*d4q2$$
(C340) $a552:ev5*(depq2-rt)+(pp-rctt)*d5q2$$
(C341) $bp2[5,2]:cg1*a152+cg2*a452+cg3*a552$$
(C342) $rt:rc*dttq3+tt*drcq3$$
(C343) $a153:coe*d1q3-d1q1*q3$$
(C344) $a453:ev4*(depq3+rt)+(pp+rctt)*d4q3$$
(C345) $a553:ev5*(depq3-rt)+(pp-rctt)*d5q3$$
(C346) $bp2[5,3]:cg1*a153+cg2*a453+cg3*a553$$
(C347) $rt:rc*dttq4+tt*drcq4$$
(C348) $a154:coe*d1q4-d1q1*q4$$
(C349) $a454:ev4*(depq4+rt)+(pp+rctt)*d4q4$$
(C350) $a554:ev5*(depq4-rt)+(pp-rctt)*d5q4$$
(C351) $bp2[5,4]:cg1*a154+cg2*a454+cg3*a554$$
(C352) $rt:tt*drcq5$$
(C353) $a155:coe*d1q5$$
(C354) $a455:ev4*(depq5+rt)+(pp+rctt)*d4q5$$

BPSUP

```
(C355) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5$  
(C356) bp2[5,5]:cg1*a155+cg2*a455+cg3*a555$  
(C357) diff:bp1.m-m.bp2$  
(C358) diff:ratexpand(diff);  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
(D358)  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
          [ 0 0 0 0 0 ]  
(C359) closefile(Bpsup)$  
***
```

```

(C3) bp1:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) bp2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C6) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,0,1])$
(C7) sign:1$
(C8) cgg1:(gam-1)/gam$
(C9) cgg2:1/(2*gam)$
(C10) etx:0.0$
(C11) sada:sqrt(etx**2+ety**2+etz**2)$
(C12) axt:etx/sada$
(C13) ayt:ety/sada$
(C14) azt:etz/sada$
(C15) rqrq:q2**2+q3**2+q4**2$
(C16) q6:1/q1$
(C17) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C18) prgam:pr*gam$
(C19) pp:q5+pr$
(C20) c:sqrt(prgam*q6)$
(C21) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C22) rc:q1*c$
(C23) csad:c*sada$
(C24) e1:tt*sada$
(C25) e4:e1+csad$
(C26) e5:e1-csad$
(C27) ev1:0.5*(e1+sign*abs(e1))$
(C28) ev4:0.5*(e4+sign*abs(e4))$
(C29) ev5:0.0$
(C30) cg1:cgg1$
(C31) cg2:cgg2$
(C32) cg3:0.0$
(C33) d1q1:-ev1*q6$
(C34) d1q2:etx*q6$
(C35) d1q3:ety*q6$
(C36) d1q4:etz*q6$
(C37) d1q5:0.0$
(C38) coe:gam*(gam-1)/(2*rc)$
(C39) gmlq6:(gam-1)*q6$
(C40) drcq1:coe*q5$
(C41) drcq2:-coe*q2$
(C42) drcq3:-coe*q3$
(C43) drcq4:-coe*q4$
(C44) drcq5:coe*q1$
(C45) dcq1:(drcq1-c)*q6$
(C46) dcq2:drcq2*q6$
(C47) dcq3:drcq3*q6$
(C48) dcq4:drcq4*q6$
(C49) dcq5:drcq5*q6$

```

(C50) depq1:0.5*gm1q6*rqrq*q6\$
(C51) depq2:-q2*gm1q6\$
(C52) depq3:-q3*gm1q6\$
(C53) depq4:-q4*gm1q6\$
(C54) depq5:gam\$
(C55) dttq1:-tt*q6\$
(C56) dttq2:axt*q6\$
(C57) dttq3:ayt*q6\$
(C58) dttq4:azt*q6\$
(C59) dttq5:0.0\$
(C60) d4q1:sada*(dttq1+dcq1)\$
(C61) d4q2:sada*(dttq2+dcq2)\$
(C62) d4q3:sada*(dttq3+dcq3)\$
(C63) d4q4:sada*(dttq4+dcq4)\$
(C64) d4q5:sada*dcq5\$
(C65) d5q1:sada*(dttq1-dcq1)\$
(C66) d5q2:sada*(dttq2-dcq2)\$
(C67) d5q3:sada*(dttq3-dcq3)\$
(C68) d5q4:sada*(dttq4-dcq4)\$
(C69) d5q5:-d4q5\$
(C70) a411:ev4+q1*d4q1\$
(C71) a511:ev5+q1*d5q1\$
(C72) bp1[1,1]:cg2*a411+cg3*a511\$
(C73) bp1[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C74) bp1[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C75) bp1[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C76) bp1[1,5]: (cg2*d4q5+cg3*d5q5)*q1\$
(C77) rcaxt:rc*axt\$
(C78) ev4ax:ev4*axt\$
(C79) ev5ax:ev5*axt\$
(C80) coe1:q2+rcaxt\$
(C81) coe:q2-rcaxt\$
(C82) a121:q2*d1q1\$
(C83) a421:ev4ax*drcq1+coe1*d4q1\$
(C84) a521:-ev5ax*drcq1+coe*d5q1\$
(C85) bp1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C86) a122:q2*d1q2+ev1\$
(C87) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C88) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C89) bp1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C90) a123:q2*d1q3\$
(C91) a423:ev4ax*drcq3+coe1*d4q3\$
(C92) a523:-ev5ax*drcq3+coe*d5q3\$
(C93) bp1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C94) a124:q2*d1q4\$
(C95) a424:ev4ax*drcq4+coe1*d4q4\$
(C96) a524:-ev5ax*drcq4+coe*d5q4\$
(C97) bp1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C98) a125:q2*d1q5\$
(C99) a425:ev4ax*drcq5+coe1*d4q5\$
(C100) a525:-ev5ax*drcq5+coe*d5q5\$

(C101) bp1[2,5]:cg1*a125+cg2*a425+cg3*a525\$
(C102) rcayt:rc*ayt\$
(C103) ev4ay:ev4*ayt\$
(C104) ev5ay:ev5*ayt\$
(C105) coe1:q3+rcayt\$
(C106) coe:q3-rcayt\$
(C107) a131:q3*d1q1\$
(C108) a431:ev4ay*drcq1+coe1*d4q1\$
(C109) a531:-ev5ay*drcq1+coe*d5q1\$
(C110) bp1[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C111) a132:q3*d1q2\$
(C112) a432:ev4ay*drcq2+coe1*d4q2\$
(C113) a532:-ev5ay*drcq2+coe*d5q2\$
(C114) bp1[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C115) a133:q3*d1q3+ev1\$
(C116) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C117) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C118) bp1[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C119) a134:q3*d1q4\$
(C120) a434:ev4ay*drcq4+coe1*d4q4\$
(C121) a534:-ev5ay*drcq4+coe*d5q4\$
(C122) bp1[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C123) a135:q3*d1q5\$
(C124) a435:ev4ay*drcq5+coe1*d4q5\$
(C125) a535:-ev5ay*drcq5+coe*d5q5\$
(C126) bp1[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C127) rcazt:rc*azt\$
(C128) ev4az:ev4*azt\$
(C129) ev5az:ev5*azt\$
(C130) coe1:q4+rcazt\$
(C131) coe:q4-rcazt\$
(C132) a141:q4*d1q1\$
(C133) a441:ev4az*drcq1+coe1*d4q1\$
(C134) a541:-ev5az*drcq1+coe*d5q1\$
(C135) bp1[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C136) a142:q4*d1q2\$
(C137) a442:ev4az*drcq2+coe1*d4q2\$
(C138) a542:-ev5az*drcq2+coe*d5q2\$
(C139) bp1[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C140) a143:q4*d1q3\$
(C141) a443:ev4az*drcq3+coe1*d4q3\$
(C142) a543:-ev5az*drcq3+coe*d5q3\$
(C143) bp1[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C144) a144:q4*d1q4+ev1\$
(C145) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C146) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C147) bp1[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C148) a145:q4*d1q5\$
(C149) a445:ev4az*drcq5+coe1*d4q5\$
(C150) a545:-ev5az*drcq5+coe*d5q5\$
(C151) bp1[4,5]:cg1*a145+cg2*a445+cg3*a545\$

(C152) rctt:rc*tt\$
(C153) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C154) rt:rc*dttq1+tt*drcq1\$
(C155) a151:2*coe*d1q1\$
(C156) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C157) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C158) bp1[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C159) rt:rc*dttq2+tt*drcq2\$
(C160) a152:coe*d1q2-d1q1*q2\$
(C161) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C162) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C163) bp1[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C164) rt:rc*dttq3+tt*drcq3\$
(C165) a153:coe*d1q3-d1q1*q3\$
(C166) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C167) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C168) bp1[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C169) rt:rc*dttq4+tt*drcq4\$
(C170) a154:coe*d1q4-d1q1*q4\$
(C171) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C172) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C173) bp1[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C174) rt:tt*drcq5\$
(C175) a155:coe*d1q5\$
(C176) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C177) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C178) bp1[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C179) q1:q1\$
(C180) q2:q2\$
(C181) q3:q3\$
(C182) q4:-q4\$
(C183) q5:q5\$
(C184) sign:1\$
(C185) etz:-etz;
(C186) cgg1:(gam-1)/gam\$
(C187) cgg2:1/(2*gam)\$
(C188) sada:sqrt(etx**2+ety**2+etz**2)\$
(C189) axt:etx/sada\$
(C190) ayt:ety/sada\$
(C191) azt:etz/sada\$
(C192) rqrq:q2**2+q3**2+q4**2\$
(C193) q6:1/q1\$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C195) prgam:pr*gam\$
(C196) pp:q5+pr\$
(C197) c:sqrt(prgam*q6)\$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C199) rc:q1*c\$
(C200) csad:c*sada\$
(C201) e1:tt*sada\$
(C202) e4:e1+csad\$

```

(C203) e5:e1-csad$
(C204) ev1:0.5*(e1+sign*abs(e1))$
(C205) ev4:0.5*(e4+sign*abs(e4))$
(C206) ev5:0.0$
(C207) cg1:cgg1$
(C208) cg2:cgg2$
(C209) cg3:0.0$
(C210) d1q1:-ev1*q6$
(C211) d1q2:etx*q6$
(C212) d1q3:ety*q6$
(C213) d1q4:etz*q6$
(C214) d1q5:0.0$
(C215) coe:gam*(gam-1)/(2*rc)$
(C216) gm1q6:(gam-1)*q6$
(C217) drcq1:coe*q5$
(C218) drcq2:-coe*q2$
(C219) drcq3:-coe*q3$
(C220) drcq4:-coe*q4$
(C221) drcq5:coe*q1$
(C222) dcq1:(drcq1-c)*q6$
(C223) dcq2:drcq2*q6$
(C224) dcq3:drcq3*q6$
(C225) dcq4:drcq4*q6$
(C226) dcq5:drcq5*q6$
(C227) depq1:0.5*gm1q6*rqrq*q6$
(C228) depq2:-q2*gm1q6$
(C229) depq3:-q3*gm1q6$
(C230) depq4:-q4*gm1q6$
(C231) depq5:gam$
(C232) dttq1:-tt*q6$
(C233) dttq2:axt*q6$
(C234) dttq3:ayt*q6$
(C235) dttq4:azt*q6$
(C236) dttq5:0.0$
(C237) d4q1:sada*(dttq1+dcq1)$
(C238) d4q2:sada*(dttq2+dcq2)$
(C239) d4q3:sada*(dttq3+dcq3)$
(C240) d4q4:sada*(dttq4+dcq4)$
(C241) d4q5:sada*dcq5$
(C242) d5q1:sada*(dttq1-dcq1)$
(C243) d5q2:sada*(dttq2-dcq2)$
(C244) d5q3:sada*(dttq3-dcq3)$
(C245) d5q4:sada*(dttq4-dcq4)$
(C246) d5q5:-d4q5$
(C247) a411:ev4+q1*d4q1$
(C248) a511:ev5+q1*d5q1$
(C249) bp2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],
[0,0,0,0,0])$
(C250) bp2[1,1]:cg2*a411+cg3*a511$
(C251) bp2[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C252) bp2[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$

```

(C253) $bp2[1,4] : (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$$
(C254) $bp2[1,5] : (cg2*d4q5+cg3*d5q5)*q1\$$
(C255) $rcaxt:rc*axt\$$
(C256) $ev4ax:ev4*axt\$$
(C257) $ev5ax:ev5*axt\$$
(C258) $coe1:q2+rcaxt\$$
(C259) $coe:q2-rcaxt\$$
(C260) $a121:q2*d1q1\$$
(C261) $a421:ev4ax*drcq1+coe1*d4q1\$$
(C262) $a521:-ev5ax*drcq1+coe*d5q1\$$
(C263) $bp2[2,1]:cg1*a121+cg2*a421+cg3*a521\$$
(C264) $a122:q2*d1q2+ev1\$$
(C265) $a422:ev4+ev4ax*drcq2+coe1*d4q2\$$
(C266) $a522:ev5-ev5ax*drcq2+coe*d5q2\$$
(C267) $bp2[2,2]:cg1*a122+cg2*a422+cg3*a522\$$
(C268) $a123:q2*d1q3\$$
(C269) $a423:ev4ax*drcq3+coe1*d4q3\$$
(C270) $a523:-ev5ax*drcq3+coe*d5q3\$$
(C271) $bp2[2,3]:cg1*a123+cg2*a423+cg3*a523\$$
(C272) $a124:q2*d1q4\$$
(C273) $a424:ev4ax*drcq4+coe1*d4q4\$$
(C274) $a524:-ev5ax*drcq4+coe*d5q4\$$
(C275) $bp2[2,4]:cg1*a124+cg2*a424+cg3*a524\$$
(C276) $a125:q2*d1q5\$$
(C277) $a425:ev4ax*drcq5+coe1*d4q5\$$
(C278) $a525:-ev5ax*drcq5+coe*d5q5\$$
(C279) $bp2[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C280) $rcayt:rc*ayt\$$
(C281) $ev4ay:ev4*ayt\$$
(C282) $ev5ay:ev5*ayt\$$
(C283) $coe1:q3+rcayt\$$
(C284) $coe:q3-rcayt\$$
(C285) $a131:q3*d1q1\$$
(C286) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C287) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C288) $bp2[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C289) $a132:q3*d1q2\$$
(C290) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C291) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C292) $bp2[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C293) $a133:q3*d1q3+ev1\$$
(C294) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C295) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C296) $bp2[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C297) $a134:q3*d1q4\$$
(C298) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C299) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C300) $bp2[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C301) $a135:q3*d1q5\$$
(C302) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C303) $a535:-ev5ay*drcq5+coe*d5q5\$$

(C304) $bp2[3,5]:cg1*a135+cg2*a435+cg3*a535\$$
(C305) $rcazt:rc*azt\$$
(C306) $ev4az:ev4*azt\$$
(C307) $ev5az:ev5*azt\$$
(C308) $coe1:q4+rcazt\$$
(C309) $coe:q4-rcazt\$$
(C310) $a141:q4*d1q1\$$
(C311) $a441:ev4az*drcq1+coe1*d4q1\$$
(C312) $a541:-ev5az*drcq1+coe*d5q1\$$
(C313) $bp2[4,1]:cg1*a141+cg2*a441+cg3*a541\$$
(C314) $a142:q4*d1q2\$$
(C315) $a442:ev4az*drcq2+coe1*d4q2\$$
(C316) $a542:-ev5az*drcq2+coe*d5q2\$$
(C317) $bp2[4,2]:cg1*a142+cg2*a442+cg3*a542\$$
(C318) $a143:q4*d1q3\$$
(C319) $a443:ev4az*drcq3+coe1*d4q3\$$
(C320) $a543:-ev5az*drcq3+coe*d5q3\$$
(C321) $bp2[4,3]:cg1*a143+cg2*a443+cg3*a543\$$
(C322) $a144:q4*d1q4+ev1\$$
(C323) $a444:ev4+ev4az*drcq4+coe1*d4q4\$$
(C324) $a544:ev5-ev5az*drcq4+coe*d5q4\$$
(C325) $bp2[4,4]:cg1*a144+cg2*a444+cg3*a544\$$
(C326) $a145:q4*d1q5\$$
(C327) $a445:ev4az*drcq5+coe1*d4q5\$$
(C328) $a545:-ev5az*drcq5+coe*d5q5\$$
(C329) $bp2[4,5]:cg1*a145+cg2*a445+cg3*a545\$$
(C330) $rctt:rc*tt\$$
(C331) $coe:0.5*(q2**2+q3**2+q4**2)*q6\$$
(C332) $rt:rc*dttq1+tt*drcq1\$$
(C333) $a151:2*coe*d1q1\$$
(C334) $a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$$
(C335) $a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$$
(C336) $bp2[5,1]:cg1*a151+cg2*a451+cg3*a551\$$
(C337) $rt:rc*dttq2+tt*drcq2\$$
(C338) $a152:coe*d1q2-d1q1*q2\$$
(C339) $a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$$
(C340) $a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$$
(C341) $bp2[5,2]:cg1*a152+cg2*a452+cg3*a552\$$
(C342) $rt:rc*dttq3+tt*drcq3\$$
(C343) $a153:coe*d1q3-d1q1*q3\$$
(C344) $a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$$
(C345) $a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$$
(C346) $bp2[5,3]:cg1*a153+cg2*a453+cg3*a553\$$
(C347) $rt:rc*dttq4+tt*drcq4\$$
(C348) $a154:coe*d1q4-d1q1*q4\$$
(C349) $a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$$
(C350) $a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$$
(C351) $bp2[5,4]:cg1*a154+cg2*a454+cg3*a554\$$
(C352) $rt:tt*drcq5\$$
(C353) $a155:coe*d1q5\$$
(C354) $a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$$

BPSUB

(C355) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C356) bp2[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C357) diff:bp1.m-m.bp2\$
(C358) diff:ratexpand(diff);
[0 0 0 0 0]
[]
[0 0 0 0 0]
[]
(D358) [0 0 0 0 0]
[]
[0 0 0 0 0]
[]
[0 0 0 0 0]
[]
[0 0 0 0 0]
[]
(C359) closefile(Bpsub)\$

```

(C3) bm1:=matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) bm2:=matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) m:=matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C6) diff:=matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C7) sign:=-1$
(C8) cgg1:=(gam-1)/gam$
(C9) cgg2:=1/(2*gam)$
(C10) etx:=0.0$
(C11) sada:=sqrt(etx**2+ety**2+etz**2)$
(C12) axt:=etx/sada$
(C13) ayt:=ety/sada$
(C14) azt:=etz/sada$
(C15) rqrq:=q2**2+q3**2+q4**2$
(C16) q6:=1/q1$
(C17) pr:=(gam-1)*(q5-0.5*rqrq*q6)$
(C18) prgam:=pr*gam$
(C19) pp:=q5+pr$
(C20) c:=sqrt(prgam*q6)$
(C21) tt:=(q2*axt+q3*ayt+q4*azt)*q6$
(C22) rc:=q1*c$
(C23) csad:=c*sada$
(C24) e1:=tt*sada$
(C25) e4:=e1+csad$
(C26) e5:=e1-csad$
(C27) ev1:=0.0$
(C28) ev4:=0.0$
(C29) ev5:=0.0$
(C30) cg1:=0.0$
(C31) cg2:=0.0$
(C32) cg3:=0.0$
(C33) d1q1:=-ev1*q6$
(C34) d1q2:=etx*q6$
(C35) d1q3:=ety*q6$
(C36) d1q4:=etz*q6$
(C37) d1q5:=0.0$
(C38) coe:=gam*(gam-1)/(2*rc)$
(C39) gmlq6:=(gam-1)*q6$
(C40) drcq1:=coe*q5$
(C41) drcq2:=-coe*q2$
(C42) drcq3:=-coe*q3$
(C43) drcq4:=-coe*q4$
(C44) drcq5:=coe*q1$
(C45) dcq1:=(drcq1-c)*q6$
(C46) dcq2:=drcq2*q6$
(C47) dcq3:=drcq3*q6$
(C48) dcq4:=drcq4*q6$
(C49) dcq5:=drcq5*q6$

```

(C50) depq1:0.5*gm1q6*rqrq*q6\$
(C51) depq2:-q2*gm1q6\$
(C52) depq3:-q3*gm1q6\$
(C53) depq4:-q4*gm1q6\$
(C54) depq5:gam\$
(C55) dttq1:-tt*q6\$
(C56) dttq2:axt*q6\$
(C57) dttq3:ayt*q6\$
(C58) dttq4:azt*q6\$
(C59) dttq5:0.0\$
(C60) d4q1:sada*(dttq1+dcq1)\$
(C61) d4q2:sada*(dttq2+dcq2)\$
(C62) d4q3:sada*(dttq3+dcq3)\$
(C63) d4q4:sada*(dttq4+dcq4)\$
(C64) d4q5:sada*dcq5\$
(C65) d5q1:sada*(dttq1-dcq1)\$
(C66) d5q2:sada*(dttq2-dcq2)\$
(C67) d5q3:sada*(dttq3-dcq3)\$
(C68) d5q4:sada*(dttq4-dcq4)\$
(C69) d5q5:-d4q5\$
(C70) a411:ev4+q1*d4q1\$
(C71) a511:ev5+q1*d5q1\$
(C72) bm1[1,1]:cg2*a411+cg3*a511\$
(C73) bm1[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C74) bm1[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C75) bm1[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C76) bm1[1,5]: (cg2*d4q5+cg3*d5q5)*q1\$
(C77) rcaxt:rc*axt\$
(C78) ev4ax:ev4*axt\$
(C79) ev5ax:ev5*axt\$
(C80) coe1:q2+rcaxt\$
(C81) coe:q2-rcaxt\$
(C82) a121:q2*d1q1\$
(C83) a421:ev4ax*drcq1+coe1*d4q1\$
(C84) a521:-ev5ax*drcq1+coe*d5q1\$
(C85) bm1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C86) a122:q2*d1q2+ev1\$
(C87) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C88) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C89) bm1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C90) a123:q2*d1q3\$
(C91) a423:ev4ax*drcq3+coe1*d4q3\$
(C92) a523:-ev5ax*drcq3+coe*d5q3\$
(C93) bm1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C94) a124:q2*d1q4\$
(C95) a424:ev4ax*drcq4+coe1*d4q4\$
(C96) a524:-ev5ax*drcq4+coe*d5q4\$
(C97) bm1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C98) a125:q2*d1q5\$
(C99) a425:ev4ax*drcq5+coe1*d4q5\$
(C100) a525:-ev5ax*drcq5+coe*d5q5\$

(C101) $b_{m1}[2,5]:c_{g1} \cdot a_{125} + c_{g2} \cdot a_{425} + c_{g3} \cdot a_{525}$ \$
(C102) $r_{cayt}:r_c \cdot a_{yt}$ \$
(C103) $e_{v4ay}:e_{v4} \cdot a_{yt}$ \$
(C104) $e_{v5ay}:e_{v5} \cdot a_{yt}$ \$
(C105) $c_{oe1}:q_3 + r_{cayt}$ \$
(C106) $c_{oe}:q_3 - r_{cayt}$ \$
(C107) $a_{131}:q_3 \cdot d_{1q1}$ \$
(C108) $a_{431}:e_{v4ay} \cdot d_{rcq1} + c_{oe1} \cdot d_{4q1}$ \$
(C109) $a_{531}:-e_{v5ay} \cdot d_{rcq1} + c_{oe} \cdot d_{5q1}$ \$
(C110) $b_{m1}[3,1]:c_{g1} \cdot a_{131} + c_{g2} \cdot a_{431} + c_{g3} \cdot a_{531}$ \$
(C111) $a_{132}:q_3 \cdot d_{1q2}$ \$
(C112) $a_{432}:e_{v4ay} \cdot d_{rcq2} + c_{oe1} \cdot d_{4q2}$ \$
(C113) $a_{532}:-e_{v5ay} \cdot d_{rcq2} + c_{oe} \cdot d_{5q2}$ \$
(C114) $b_{m1}[3,2]:c_{g1} \cdot a_{132} + c_{g2} \cdot a_{432} + c_{g3} \cdot a_{532}$ \$
(C115) $a_{133}:q_3 \cdot d_{1q3} + e_{v1}$ \$
(C116) $a_{433}:e_{v4} + e_{v4ay} \cdot d_{rcq3} + c_{oe1} \cdot d_{4q3}$ \$
(C117) $a_{533}:e_{v5} - e_{v5ay} \cdot d_{rcq3} + c_{oe} \cdot d_{5q3}$ \$
(C118) $b_{m1}[3,3]:c_{g1} \cdot a_{133} + c_{g2} \cdot a_{433} + c_{g3} \cdot a_{533}$ \$
(C119) $a_{134}:q_3 \cdot d_{1q4}$ \$
(C120) $a_{434}:e_{v4ay} \cdot d_{rcq4} + c_{oe1} \cdot d_{4q4}$ \$
(C121) $a_{534}:-e_{v5ay} \cdot d_{rcq4} + c_{oe} \cdot d_{5q4}$ \$
(C122) $b_{m1}[3,4]:c_{g1} \cdot a_{134} + c_{g2} \cdot a_{434} + c_{g3} \cdot a_{534}$ \$
(C123) $a_{135}:q_3 \cdot d_{1q5}$ \$
(C124) $a_{435}:e_{v4ay} \cdot d_{rcq5} + c_{oe1} \cdot d_{4q5}$ \$
(C125) $a_{535}:-e_{v5ay} \cdot d_{rcq5} + c_{oe} \cdot d_{5q5}$ \$
(C126) $b_{m1}[3,5]:c_{g1} \cdot a_{135} + c_{g2} \cdot a_{435} + c_{g3} \cdot a_{535}$ \$
(C127) $r_{cazt}:r_c \cdot a_{zt}$ \$
(C128) $e_{v4az}:e_{v4} \cdot a_{zt}$ \$
(C129) $e_{v5az}:e_{v5} \cdot a_{zt}$ \$
(C130) $c_{oe1}:q_4 + r_{cazt}$ \$
(C131) $c_{oe}:q_4 - r_{cazt}$ \$
(C132) $a_{141}:q_4 \cdot d_{1q1}$ \$
(C133) $a_{441}:e_{v4az} \cdot d_{rcq1} + c_{oe1} \cdot d_{4q1}$ \$
(C134) $a_{541}:-e_{v5az} \cdot d_{rcq1} + c_{oe} \cdot d_{5q1}$ \$
(C135) $b_{m1}[4,1]:c_{g1} \cdot a_{141} + c_{g2} \cdot a_{441} + c_{g3} \cdot a_{541}$ \$
(C136) $a_{142}:q_4 \cdot d_{1q2}$ \$
(C137) $a_{442}:e_{v4az} \cdot d_{rcq2} + c_{oe1} \cdot d_{4q2}$ \$
(C138) $a_{542}:-e_{v5az} \cdot d_{rcq2} + c_{oe} \cdot d_{5q2}$ \$
(C139) $b_{m1}[4,2]:c_{g1} \cdot a_{142} + c_{g2} \cdot a_{442} + c_{g3} \cdot a_{542}$ \$
(C140) $a_{143}:q_4 \cdot d_{1q3}$ \$
(C141) $a_{443}:e_{v4az} \cdot d_{rcq3} + c_{oe1} \cdot d_{4q3}$ \$
(C142) $a_{543}:-e_{v5az} \cdot d_{rcq3} + c_{oe} \cdot d_{5q3}$ \$
(C143) $b_{m1}[4,3]:c_{g1} \cdot a_{143} + c_{g2} \cdot a_{443} + c_{g3} \cdot a_{543}$ \$
(C144) $a_{144}:q_4 \cdot d_{1q4} + e_{v1}$ \$
(C145) $a_{444}:e_{v4} + e_{v4az} \cdot d_{rcq4} + c_{oe1} \cdot d_{4q4}$ \$
(C146) $a_{544}:e_{v5} - e_{v5az} \cdot d_{rcq4} + c_{oe} \cdot d_{5q4}$ \$
(C147) $b_{m1}[4,4]:c_{g1} \cdot a_{144} + c_{g2} \cdot a_{444} + c_{g3} \cdot a_{544}$ \$
(C148) $a_{145}:q_4 \cdot d_{1q5}$ \$
(C149) $a_{445}:e_{v4az} \cdot d_{rcq5} + c_{oe1} \cdot d_{4q5}$ \$
(C150) $a_{545}:-e_{v5az} \cdot d_{rcq5} + c_{oe} \cdot d_{5q5}$ \$
(C151) $b_{m1}[4,5]:c_{g1} \cdot a_{145} + c_{g2} \cdot a_{445} + c_{g3} \cdot a_{545}$ \$

(C152) rctt:rc*tt\$
(C153) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C154) rt:rc*dttq1+tt*drcq1\$
(C155) a151:2*coe*d1q1\$
(C156) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C157) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C158) bm1[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C159) rt:rc*dttq2+tt*drcq2\$
(C160) a152:coe*d1q2-d1q1*q2\$
(C161) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C162) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C163) bm1[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C164) rt:rc*dttq3+tt*drcq3\$
(C165) a153:coe*d1q3-d1q1*q3\$
(C166) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C167) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C168) bm1[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C169) rt:rc*dttq4+tt*drcq4\$
(C170) a154:coe*d1q4-d1q1*q4\$
(C171) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C172) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C173) bm1[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C174) rt:tt*drcq5\$
(C175) a155:coe*d1q5\$
(C176) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C177) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C178) bm1[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C179) q1:q1\$
(C180) q2:q2\$
(C181) q3:q3\$
(C182) q4:-q4\$
(C183) q5:q5\$
(C184) sign:1\$
(C185) etz:-etz;
(C186) cgg1:(gam-1)/gam\$
(C187) cgg2:1/(2*gam)\$
(C188) sada:sqrt(etx**2+ety**2+etz**2)\$
(C189) axt:etx/sada\$
(C190) ayt:ety/sada\$
(C191) azt:etz/sada\$
(C192) rqrq:q2**2+q3**2+q4**2\$
(C193) q6:1/q1\$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C195) prgam:pr*gam\$
(C196) pp:q5+pr\$
(C197) c:sqrt(prgam*q6)\$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C199) rc:q1*c\$
(C200) csad:c*sada\$
(C201) e1:tt*sada\$
(C202) e4:e1+csad\$

```

(C203) e5:e1-csad$
(C204) ev1:0.0$ 
(C205) ev4:0.0$ 
(C206) ev5:0.0$ 
(C207) cg1:0.0$ 
(C208) cg2:0.0$ 
(C209) cg3:0.0$ 
(C210) d1q1:-ev1*q6$ 
(C211) d1q2:etx*q6$ 
(C212) d1q3:ety*q6$ 
(C213) d1q4:etz*q6$ 
(C214) d1q5:0.0$ 
(C215) coe:gam*(gam-1)/(2*rc)$ 
(C216) gmlq6:(gam-1)*q6$ 
(C217) drcq1:coe*q5$ 
(C218) drcq2:-coe*q2$ 
(C219) drcq3:-coe*q3$ 
(C220) drcq4:-coe*q4$ 
(C221) drcq5:coe*q1$ 
(C222) dcq1:(drcq1-c)*q6$ 
(C223) dcq2:drcq2*q6$ 
(C224) dcq3:drcq3*q6$ 
(C225) dcq4:drcq4*q6$ 
(C226) dcq5:drcq5*q6$ 
(C227) depq1:0.5*gmlq6*rqrq*q6$ 
(C228) depq2:-q2*gmlq6$ 
(C229) depq3:-q3*gmlq6$ 
(C230) depq4:-q4*gmlq6$ 
(C231) depq5:gam$ 
(C232) dttq1:-tt*q6$ 
(C233) dttq2:axt*q6$ 
(C234) dttq3:ayt*q6$ 
(C235) dttq4:azt*q6$ 
(C236) dttq5:0.0$ 
(C237) d4q1:sada*(dttq1+dcq1)$ 
(C238) d4q2:sada*(dttq2+dcq2)$ 
(C239) d4q3:sada*(dttq3+dcq3)$ 
(C240) d4q4:sada*(dttq4+dcq4)$ 
(C241) d4q5:sada*dcq5$ 
(C242) d5q1:sada*(dttq1-dcq1)$ 
(C243) d5q2:sada*(dttq2-dcq2)$ 
(C244) d5q3:sada*(dttq3-dcq3)$ 
(C245) d5q4:sada*(dttq4-dcq4)$ 
(C246) d5q5:-d4q5$ 
(C247) a411:ev4+q1*d4q1$ 
(C248) a511:ev5+q1*d5q1$ 
(C249) bm2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],
[0,0,0,0,0])$ 
(C250) bm2[1,1]:cg2*a411+cg3*a511$ 
(C251) bm2[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$ 
(C252) bm2[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$ 

```

(C253) $bm2[1,4] : (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$$
(C254) $bm2[1,5] : (cg2*d4q5+cg3*d5q5)*q1\$$
(C255) $rcaxt:rc*axt\$$
(C256) $ev4ax:ev4*axt\$$
(C257) $ev5ax:ev5*axt\$$
(C258) $coe1:q2+rcaxt\$$
(C259) $coe:q2-rcaxt\$$
(C260) $a121:q2*d1q1\$$
(C261) $a421:ev4ax*drcq1+coe1*d4q1\$$
(C262) $a521:-ev5ax*drcq1+coe*d5q1\$$
(C263) $bm2[2,1]:cg1*a121+cg2*a421+cg3*a521\$$
(C264) $a122:q2*d1q2+ev1\$$
(C265) $a422:ev4+ev4ax*drcq2+coe1*d4q2\$$
(C266) $a522:ev5-ev5ax*drcq2+coe*d5q2\$$
(C267) $bm2[2,2]:cg1*a122+cg2*a422+cg3*a522\$$
(C268) $a123:q2*d1q3\$$
(C269) $a423:ev4ax*drcq3+coe1*d4q3\$$
(C270) $a523:-ev5ax*drcq3+coe*d5q3\$$
(C271) $bm2[2,3]:cg1*a123+cg2*a423+cg3*a523\$$
(C272) $a124:q2*d1q4\$$
(C273) $a424:ev4ax*drcq4+coe1*d4q4\$$
(C274) $a524:-ev5ax*drcq4+coe*d5q4\$$
(C275) $bm2[2,4]:cg1*a124+cg2*a424+cg3*a524\$$
(C276) $a125:q2*d1q5\$$
(C277) $a425:ev4ax*drcq5+coe1*d4q5\$$
(C278) $a525:-ev5ax*drcq5+coe*d5q5\$$
(C279) $bm2[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C280) $rcayt:rc*ayt\$$
(C281) $ev4ay:ev4*ayt\$$
(C282) $ev5ay:ev5*ayt\$$
(C283) $coe1:q3+rcayt\$$
(C284) $coe:q3-rcayt\$$
(C285) $a131:q3*d1q1\$$
(C286) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C287) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C288) $bm2[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C289) $a132:q3*d1q2\$$
(C290) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C291) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C292) $bm2[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C293) $a133:q3*d1q3+ev1\$$
(C294) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C295) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C296) $bm2[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C297) $a134:q3*d1q4\$$
(C298) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C299) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C300) $bm2[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C301) $a135:q3*d1q5\$$
(C302) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C303) $a535:-ev5ay*drcq5+coe*d5q5\$$

(C304) $bm2[3,5]:cg1*a135+cg2*a435+cg3*a535$$
(C305) $rcazt:rc*azt$$
(C306) $ev4az:ev4*azt$$
(C307) $ev5az:ev5*azt$$
(C308) $coe1:q4+rcazt$$
(C309) $coe:q4-rcazt$$
(C310) $a141:q4*d1q1$$
(C311) $a441:ev4az*drcq1+coe1*d4q1$$
(C312) $a541:-ev5az*drcq1+coe*d5q1$$
(C313) $bm2[4,1]:cg1*a141+cg2*a441+cg3*a541$$
(C314) $a142:q4*d1q2$$
(C315) $a442:ev4az*drcq2+coe1*d4q2$$
(C316) $a542:-ev5az*drcq2+coe*d5q2$$
(C317) $bm2[4,2]:cg1*a142+cg2*a442+cg3*a542$$
(C318) $a143:q4*d1q3$$
(C319) $a443:ev4az*drcq3+coe1*d4q3$$
(C320) $a543:-ev5az*drcq3+coe*d5q3$$
(C321) $bm2[4,3]:cg1*a143+cg2*a443+cg3*a543$$
(C322) $a144:q4*d1q4+ev1$$
(C323) $a444:ev4+ev4az*drcq4+coe1*d4q4$$
(C324) $a544:ev5-ev5az*drcq4+coe*d5q4$$
(C325) $bm2[4,4]:cg1*a144+cg2*a444+cg3*a544$$
(C326) $a145:q4*d1q5$$
(C327) $a445:ev4az*drcq5+coe1*d4q5$$
(C328) $a545:-ev5az*drcq5+coe*d5q5$$
(C329) $bm2[4,5]:cg1*a145+cg2*a445+cg3*a545$$
(C330) $rctt:rc*tt$$
(C331) $coe:0.5*(q2**2+q3**2+q4**2)*q6$$
(C332) $rt:rc*dttq1+tt*drcq1$$
(C333) $a151:2*coe*d1q1$$
(C334) $a451:ev4*(depq1+rt)+(pp+rctt)*d4q1$$
(C335) $a551:ev5*(depq1-rt)+(pp-rctt)*d5q1$$
(C336) $bm2[5,1]:cg1*a151+cg2*a451+cg3*a551$$
(C337) $rt:rc*dttq2+tt*drcq2$$
(C338) $a152:coe*d1q2-d1q1*q2$$
(C339) $a452:ev4*(depq2+rt)+(pp+rctt)*d4q2$$
(C340) $a552:ev5*(depq2-rt)+(pp-rctt)*d5q2$$
(C341) $bm2[5,2]:cg1*a152+cg2*a452+cg3*a552$$
(C342) $rt:rc*dttq3+tt*drcq3$$
(C343) $a153:coe*d1q3-d1q1*q3$$
(C344) $a453:ev4*(depq3+rt)+(pp+rctt)*d4q3$$
(C345) $a553:ev5*(depq3-rt)+(pp-rctt)*d5q3$$
(C346) $bm2[5,3]:cg1*a153+cg2*a453+cg3*a553$$
(C347) $rt:rc*dttq4+tt*drcq4$$
(C348) $a154:coe*d1q4-d1q1*q4$$
(C349) $a454:ev4*(depq4+rt)+(pp+rctt)*d4q4$$
(C350) $a554:ev5*(depq4-rt)+(pp-rctt)*d5q4$$
(C351) $bm2[5,4]:cg1*a154+cg2*a454+cg3*a554$$
(C352) $rt:tt*drcq5$$
(C353) $a155:coe*d1q5$$
(C354) $a455:ev4*(depq5+rt)+(pp+rctt)*d4q5$$

(C355) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C356) bm2[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C357) diff:bm1.m-m.bm2\$
(C358) diff:ratexpand(diff);
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
(D358)
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
(C359) closefile(Bmsup)\$
■

```

(C3) bm1:=matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C4) bm2:=matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C5) m:=matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C6) diff:=matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0
,0,0,0,0])$
(C7) sign:=-1$
(C8) cgg1:=(gam-1)/gam$
(C9) cgg2:=1/(2*gam)$
(C10) etx:=0.0$
```

$$(C11) \text{sada} := \sqrt{etx^2 + ety^2 + etz^2}$$

$$(C12) \text{axt} := etx / \text{sada}$$

$$(C13) \text{ayt} := ety / \text{sada}$$

$$(C14) \text{azt} := etz / \text{sada}$$

$$(C15) \text{rqrq} := q2^2 + q3^2 + q4^2$$

$$(C16) q6 := 1/q1$$

$$(C17) pr := (\text{gam}-1) * (q5 - 0.5 * \text{rqrq} * q6)$$

$$(C18) \text{prgam} := pr * \text{gam}$$

$$(C19) pp := q5 + pr$$

$$(C20) c := \sqrt{\text{prgam} * q6}$$

$$(C21) tt := (q2 * \text{axt} + q3 * \text{ayt} + q4 * \text{azt}) * q6$$

$$(C22) rc := q1 * c$$

$$(C23) csad := c * \text{sada}$$

$$(C24) e1 := tt * \text{sada}$$

$$(C25) e4 := e1 + csad$$

$$(C26) e5 := e1 - csad$$

$$(C27) ev1 := 0.0$$

$$(C28) ev4 := 0.0$$

$$(C29) ev5 := 0.5 * (e5 + sign * abs(e5))$$

$$(C30) cg1 := 0.0$$

$$(C31) cg2 := 0.0$$

$$(C32) cg3 := cgg2$$

$$(C33) d1q1 := -ev1 * q6$$

$$(C34) d1q2 := etx * q6$$

$$(C35) d1q3 := ety * q6$$

$$(C36) d1q4 := etz * q6$$

$$(C37) d1q5 := 0.0$$

$$(C38) coe := \text{gam} * (\text{gam}-1) / (2 * rc)$$

$$(C39) gm1q6 := (\text{gam}-1) * q6$$

$$(C40) drcq1 := coe * q5$$

$$(C41) drcq2 := -coe * q2$$

$$(C42) drcq3 := -coe * q3$$

$$(C43) drcq4 := -coe * q4$$

$$(C44) drcq5 := coe * q1$$

$$(C45) dcq1 := (drcq1 - c) * q6$$

$$(C46) dcq2 := drcq2 * q6$$

$$(C47) dcq3 := drcq3 * q6$$

$$(C48) dcq4 := drcq4 * q6$$

$$(C49) dcq5 := drcq5 * q6$$

(C50) depq1:0.5*gmlq6*rqrq*q6\$
(C51) depq2:-q2*gmlq6\$
(C52) depq3:-q3*gmlq6\$
(C53) depq4:-q4*gmlq6\$
(C54) depq5:gam\$
(C55) dttq1:-tt*q6\$
(C56) dttq2:axt*q6\$
(C57) dttq3:ayt*q6\$
(C58) dttq4:azt*q6\$
(C59) dttq5:0.0\$
(C60) d4q1:sada*(dttq1+dcq1)\$
(C61) d4q2:sada*(dttq2+dcq2)\$
(C62) d4q3:sada*(dttq3+dcq3)\$
(C63) d4q4:sada*(dttq4+dcq4)\$
(C64) d4q5:sada*dcq5\$
(C65) d5q1:sada*(dttq1-dcq1)\$
(C66) d5q2:sada*(dttq2-dcq2)\$
(C67) d5q3:sada*(dttq3-dcq3)\$
(C68) d5q4:sada*(dttq4-dcq4)\$
(C69) d5q5:-d4q5\$
(C70) a411:ev4+q1*d4q1\$
(C71) a511:ev5+q1*d5q1\$
(C72) bm1[1,1]:cg2*a411+cg3*a511\$
(C73) bm1[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C74) bm1[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C75) bm1[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C76) bm1[1,5]: (cg2*d4q5+cg3*d5q5)*q1\$
(C77) rcaxt:rc*axt\$
(C78) ev4ax:ev4*axt\$
(C79) ev5ax:ev5*axt\$
(C80) coe1:q2+rcaxt\$
(C81) coe:q2-rcaxt\$
(C82) a121:q2*d1q1\$
(C83) a421:ev4ax*drcq1+coe1*d4q1\$
(C84) a521:-ev5ax*drcq1+coe*d5q1\$
(C85) bm1[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C86) a122:q2*d1q2+ev1\$
(C87) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C88) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C89) bm1[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C90) a123:q2*d1q3\$
(C91) a423:ev4ax*drcq3+coe1*d4q3\$
(C92) a523:-ev5ax*drcq3+coe*d5q3\$
(C93) bm1[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C94) a124:q2*d1q4\$
(C95) a424:ev4ax*drcq4+coe1*d4q4\$
(C96) a524:-ev5ax*drcq4+coe*d5q4\$
(C97) bm1[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C98) a125:q2*d1q5\$
(C99) a425:ev4ax*drcq5+coe1*d4q5\$
(C100) a525:-ev5ax*drcq5+coe*d5q5\$

(C101) $bm1[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C102) $rcayt:rc*ayt\$$
(C103) $ev4ay:ev4*ayt\$$
(C104) $ev5ay:ev5*ayt\$$
(C105) $coe1:q3+rcayt\$$
(C106) $coe:q3-rcayt\$$
(C107) $a131:q3*d1q1\$$
(C108) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C109) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C110) $bm1[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C111) $a132:q3*d1q2\$$
(C112) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C113) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C114) $bm1[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C115) $a133:q3*d1q3+ev1\$$
(C116) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C117) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C118) $bm1[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C119) $a134:q3*d1q4\$$
(C120) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C121) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C122) $bm1[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C123) $a135:q3*d1q5\$$
(C124) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C125) $a535:-ev5ay*drcq5+coe*d5q5\$$
(C126) $bm1[3,5]:cg1*a135+cg2*a435+cg3*a535\$$
(C127) $rcazt:rc*azt\$$
(C128) $ev4az:ev4*azt\$$
(C129) $ev5az:ev5*azt\$$
(C130) $coe1:q4+rcazt\$$
(C131) $coe:q4-rcazt\$$
(C132) $a141:q4*d1q1\$$
(C133) $a441:ev4az*drcq1+coe1*d4q1\$$
(C134) $a541:-ev5az*drcq1+coe*d5q1\$$
(C135) $bm1[4,1]:cg1*a141+cg2*a441+cg3*a541\$$
(C136) $a142:q4*d1q2\$$
(C137) $a442:ev4az*drcq2+coe1*d4q2\$$
(C138) $a542:-ev5az*drcq2+coe*d5q2\$$
(C139) $bm1[4,2]:cg1*a142+cg2*a442+cg3*a542\$$
(C140) $a143:q4*d1q3\$$
(C141) $a443:ev4az*drcq3+coe1*d4q3\$$
(C142) $a543:-ev5az*drcq3+coe*d5q3\$$
(C143) $bm1[4,3]:cg1*a143+cg2*a443+cg3*a543\$$
(C144) $a144:q4*d1q4+ev1\$$
(C145) $a444:ev4+ev4az*drcq4+coe1*d4q4\$$
(C146) $a544:ev5-ev5az*drcq4+coe*d5q4\$$
(C147) $bm1[4,4]:cg1*a144+cg2*a444+cg3*a544\$$
(C148) $a145:q4*d1q5\$$
(C149) $a445:ev4az*drcq5+coe1*d4q5\$$
(C150) $a545:-ev5az*drcq5+coe*d5q5\$$
(C151) $bm1[4,5]:cg1*a145+cg2*a445+cg3*a545\$$

(C152) rctt:rc*tt\$
(C153) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C154) rt:rc*dttq1+tt*drcq1\$
(C155) a151:2*coe*d1q1\$
(C156) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C157) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C158) bm1[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C159) rt:rc*dttq2+tt*drcq2\$
(C160) a152:coe*d1q2-d1q1*q2\$
(C161) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C162) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C163) bm1[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C164) rt:rc*dttq3+tt*drcq3\$
(C165) a153:coe*d1q3-d1q1*q3\$
(C166) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C167) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C168) bm1[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C169) rt:rc*dttq4+tt*drcq4\$
(C170) a154:coe*d1q4-d1q1*q4\$
(C171) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C172) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C173) bm1[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C174) rt:tt*drcq5\$
(C175) a155:coe*d1q5\$
(C176) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C177) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C178) bm1[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C179) q1:q1\$
(C180) q2:q2\$
(C181) q3:q3\$
(C182) q4:-q4\$
(C183) q5:q5\$
(C184) etz:-etz;
(C185) cgg1:(gam-1)/gam\$
(C186) cgg2:1/(2*gam)\$
(C187) sada:sqrt(etx**2+ety**2+etz**2)\$
(C188) axt:etx/sada\$
(C189) ayt:ety/sada\$
(C190) azt:etz/sada\$
(C191) rqrq:q2**2+q3**2+q4**2\$
(C192) q6:1/q1\$
(C193) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C194) prgam:pr*gam\$
(C195) pp:q5+pr\$
(C196) c:sqrt(prgam*q6)\$
(C197) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C198) rc:q1*c\$
(C199) csad:c*sada\$
(C200) e1:tt*sada\$
(C201) e4:e1+csad\$
(C202) e5:e1-csad\$

```

(C203) ev1:0.0$
(C204) ev4:0.0$
(C205) ev5:0.5*(e5+sign*abs(e5))$
(C206) cg1:0.0$
(C207) cg2:0.0$
(C208) cg3:cgg2$
(C209) d1q1:-ev1*q6$
(C210) d1q2:etx*q6$
(C211) d1q3:ety*q6$
(C212) d1q4:etz*q6$
(C213) d1q5:0.0$
(C214) coe:gam*(gam-1)/(2*rc)$
(C215) gmlq6:(gam-1)*q6$
(C216) drcq1:coe*q5$
(C217) drcq2:-coe*q2$
(C218) drcq3:-coe*q3$
(C219) drcq4:-coe*q4$
(C220) drcq5:coe*q1$
(C221) dcq1:(drcq1-c)*q6$
(C222) dcq2:drcq2*q6$
(C223) dcq3:drcq3*q6$
(C224) dcq4:drcq4*q6$
(C225) dcq5:drcq5*q6$
(C226) depq1:0.5*gmlq6*rqrq*q6$
(C227) depq2:-q2*gmlq6$
(C228) depq3:-q3*gmlq6$
(C229) depq4:-q4*gmlq6$
(C230) depq5:gam$
(C231) dttq1:-tt*q6$
(C232) dttq2:axt*q6$
(C233) dttq3:ayt*q6$
(C234) dttq4:azt*q6$
(C235) dttq5:0.0$
(C236) d4q1:sada*(dttq1+dcq1)$
(C237) d4q2:sada*(dttq2+dcq2)$
(C238) d4q3:sada*(dttq3+dcq3)$
(C239) d4q4:sada*(dttq4+dcq4)$
(C240) d4q5:sada*dcq5$
(C241) d5q1:sada*(dttq1-dcq1)$
(C242) d5q2:sada*(dttq2-dcq2)$
(C243) d5q3:sada*(dttq3-dcq3)$
(C244) d5q4:sada*(dttq4-dcq4)$
(C245) d5q5:-d4q5$
(C246) a411:ev4+q1*d4q1$
(C247) a511:ev5+q1*d5q1$
(C248) bm2:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],
[0,0,0,0,0])$
(C249) bm2[1,1]:cg2*a411+cg3*a511$
(C250) bm2[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1$
(C251) bm2[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1$
(C252) bm2[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1$

```

(C253) $bm2[1,5] : (cg2*d4q5+cg3*d5q5)*q1\$$
(C254) $rcaxt:rc*axt\$$
(C255) $ev4ax:ev4*axt\$$
(C256) $ev5ax:ev5*axt\$$
(C257) $coe1:q2+rcaxt\$$
(C258) $coe:q2-rcaxt\$$
(C259) $a121:q2*d1q1\$$
(C260) $a421:ev4ax*drcq1+coe1*d4q1\$$
(C261) $a521:-ev5ax*drcq1+coe*d5q1\$$
(C262) $bm2[2,1]:cg1*a121+cg2*a421+cg3*a521\$$
(C263) $a122:q2*d1q2+ev1\$$
(C264) $a422:ev4+ev4ax*drcq2+coe1*d4q2\$$
(C265) $a522:ev5-ev5ax*drcq2+coe*d5q2\$$
(C266) $bm2[2,2]:cg1*a122+cg2*a422+cg3*a522\$$
(C267) $a123:q2*d1q3\$$
(C268) $a423:ev4ax*drcq3+coe1*d4q3\$$
(C269) $a523:-ev5ax*drcq3+coe*d5q3\$$
(C270) $bm2[2,3]:cg1*a123+cg2*a423+cg3*a523\$$
(C271) $a124:q2*d1q4\$$
(C272) $a424:ev4ax*drcq4+coe1*d4q4\$$
(C273) $a524:-ev5ax*drcq4+coe*d5q4\$$
(C274) $bm2[2,4]:cg1*a124+cg2*a424+cg3*a524\$$
(C275) $a125:q2*d1q5\$$
(C276) $a425:ev4ax*drcq5+coe1*d4q5\$$
(C277) $a525:-ev5ax*drcq5+coe*d5q5\$$
(C278) $bm2[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C279) $rcayt:rc*ayt\$$
(C280) $ev4ay:ev4*ayt\$$
(C281) $ev5ay:ev5*ayt\$$
(C282) $coe1:q3+rcayt\$$
(C283) $coe:q3-rcayt\$$
(C284) $a131:q3*d1q1\$$
(C285) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C286) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C287) $bm2[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C288) $a132:q3*d1q2\$$
(C289) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C290) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C291) $bm2[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C292) $a133:q3*d1q3+ev1\$$
(C293) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C294) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C295) $bm2[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C296) $a134:q3*d1q4\$$
(C297) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C298) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C299) $bm2[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C300) $a135:q3*d1q5\$$
(C301) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C302) $a535:-ev5ay*drcq5+coe*d5q5\$$
(C303) $bm2[3,5]:cg1*a135+cg2*a435+cg3*a535\$$

(C304) rcazt:rc*azt\$
(C305) ev4az:ev4*azt\$
(C306) ev5az:ev5*azt\$
(C307) coe1:q4+rcazt\$
(C308) coe:q4-rcazt\$
(C309) a141:q4*d1q1\$
(C310) a441:ev4az*drcq1+coe1*d4q1\$
(C311) a541:-ev5az*drcq1+coe*d5q1\$
(C312) bm2[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C313) a142:q4*d1q2\$
(C314) a442:ev4az*drcq2+coe1*d4q2\$
(C315) a542:-ev5az*drcq2+coe*d5q2\$
(C316) bm2[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C317) a143:q4*d1q3\$
(C318) a443:ev4az*drcq3+coe1*d4q3\$
(C319) a543:-ev5az*drcq3+coe*d5q3\$
(C320) bm2[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C321) a144:q4*d1q4+ev1\$
(C322) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C323) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C324) bm2[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C325) a145:q4*d1q5\$
(C326) a445:ev4az*drcq5+coe1*d4q5\$
(C327) a545:-ev5az*drcq5+coe*d5q5\$
(C328) bm2[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C329) rctt:rc*tt\$
(C330) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C331) rt:rc*dttq1+tt*drcq1\$
(C332) a151:2*coe*d1q1\$
(C333) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C334) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C335) bm2[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C336) rt:rc*dttq2+tt*drcq2\$
(C337) a152:coe*d1q2-d1q1*q2\$
(C338) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C339) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C340) bm2[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C341) rt:rc*dttq3+tt*drcq3\$
(C342) a153:coe*d1q3-d1q1*q3\$
(C343) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C344) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C345) bm2[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C346) rt:rc*dttq4+tt*drcq4\$
(C347) a154:coe*d1q4-d1q1*q4\$
(C348) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C349) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C350) bm2[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C351) rt:tt*drcq5\$
(C352) a155:coe*d1q5\$
(C353) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C354) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$

BMSUB

```
(C355) bm2[5,5]:=cg1*a155+cg2*a455+cg3*a555$  
(C356) diff:=bm1.m-m.bm2$  
(C357) diff:=ratexpand(diff);  
[ 0 0 0 0 0 ]  
[ ]  
[ 0 0 0 0 0 ]  
[ ]  
(D357) [ 0 0 0 0 0 ]  
[ ]  
[ 0 0 0 0 0 ]  
[ ]  
[ 0 0 0 0 0 ]  
[ ]  
[ 0 0 0 0 0 ]  
(C358) closefile(Bmsub)$  
#
```

```

(C3) cp:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C4) cm:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C5) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C6) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C7) sign:1$
(C8) cgg1:(gam-1)/gam$
(C9) cgg2:1/(2*gam)$
(C10) sada:sqrt(ztx**2+zty**2+ztz**2)$
(C11) axt:ztx/sada$
(C12) ayt:zty/sada$
(C13) azt:ztz/sada$
(C14) rqrq:q2**2+q3**2+q4**2$
(C15) q6:1/q1$
(C16) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C17) prgam:pr*gam$
(C18) pp:q5+pr$
(C19) c:sqrt(prgam*q6)$
(C20) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C21) rc:q1*c$
(C22) csad:c*sada$
(C23) e1:tt*sada$
(C24) e4:e1+csad$
(C25) e5:e1-csad$
(C26) ev1:e1$
(C27) ev4:e4$
(C28) ev5:e1$
(C29) cg1:cgg1$
(C30) cg2:cgg2$
(C31) cg3:cgg2$
(C32) d1q1:-ev1*q6$
(C33) d1q2:ztx*q6$
(C34) d1q3:zty*q6$
(C35) d1q4:ztz*q6$
(C36) d1q5:0.0$
(C37) coe:gam*(gam-1)/(2*rc)$
(C38) gm1q6:(gam-1)*q6$
(C39) drcq1:coe*q5$
(C40) drcq2:-coe*q2$
(C41) drcq3:-coe*q3$
(C42) drcq4:-coe*q4$
(C43) drcq5:coe*q1$
(C44) dcq1:(drcq1-c)*q6$
(C45) dcq2:drcq2*q6$
(C46) dcq3:drcq3*q6$
(C47) dcq4:drcq4*q6$
(C48) dcq5:drcq5*q6$
(C49) depq1:0.5*gm1q6*rqrq*q6$

```

(C50) depq2:-q2*gm1q6\$
(C51) depq3:-q3*gm1q6\$
(C52) depq4:-q4*gm1q6\$
(C53) depq5:gam\$
(C54) dttq1:-tt*q6\$
(C55) dttq2:axt*q6\$
(C56) dttq3:ayt*q6\$
(C57) dttq4:azt*q6\$
(C58) dttq5:0.0\$
(C59) d4q1:sada*(dttq1+dcq1)\$
(C60) d4q2:sada*(dttq2+dcq2)\$
(C61) d4q3:sada*(dttq3+dcq3)\$
(C62) d4q4:sada*(dttq4+dcq4)\$
(C63) d4q5:sada*dcq5\$
(C64) d5q1:sada*(dttq1-dcq1)\$
(C65) d5q2:sada*(dttq2-dcq2)\$
(C66) d5q3:sada*(dttq3-dcq3)\$
(C67) d5q4:sada*(dttq4-dcq4)\$
(C68) d5q5:-d4q5\$
(C69) a411:ev4+q1*d4q1\$
(C70) a511:ev5+q1*d5q1\$
(C71) cp[1,1]:cg2*a411+cg3*a511\$
(C72) cp[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C73) cp[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C74) cp[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C75) cp[1,5]: (cg2*d4q5+cg3*d5q5)*q1\$
(C76) rcaxt:rc*axt\$
(C77) ev4ax:ev4*axt\$
(C78) ev5ax:ev5*axt\$
(C79) coe1:q2+rcaxt\$
(C80) coe:q2-rcaxt\$
(C81) a121:q2*d1q1\$
(C82) a421:ev4ax*drcq1+coe1*d4q1\$
(C83) a521:-ev5ax*drcq1+coe*d5q1\$
(C84) cp[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C85) a122:q2*d1q2+ev1\$
(C86) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C87) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C88) cp[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C89) a123:q2*d1q3\$
(C90) a423:ev4ax*drcq3+coe1*d4q3\$
(C91) a523:-ev5ax*drcq3+coe*d5q3\$
(C92) cp[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C93) a124:q2*d1q4\$
(C94) a424:ev4ax*drcq4+coe1*d4q4\$
(C95) a524:-ev5ax*drcq4+coe*d5q4\$
(C96) cp[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C97) a125:q2*d1q5\$
(C98) a425:ev4ax*drcq5+coe1*d4q5\$
(C99) a525:-ev5ax*drcq5+coe*d5q5\$
(C100) cp[2,5]:cg1*a125+cg2*a425+cg3*a525\$

(C101) $rcayt:rc*ayt\$$
(C102) $ev4ay:ev4*ayt\$$
(C103) $ev5ay:ev5*ayt\$$
(C104) $coe1:q3+rcayt\$$
(C105) $coe:q3-rcayt\$$
(C106) $a131:q3*d1q1\$$
(C107) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C108) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C109) $cp[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C110) $a132:q3*d1q2\$$
(C111) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C112) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C113) $cp[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C114) $a133:q3*d1q3+ev1\$$
(C115) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C116) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C117) $cp[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C118) $a134:q3*d1q4\$$
(C119) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C120) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C121) $cp[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C122) $a135:q3*d1q5\$$
(C123) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C124) $a535:-ev5ay*drcq5+coe*d5q5\$$
(C125) $cp[3,5]:cg1*a135+cg2*a435+cg3*a535\$$
(C126) $rcazt:rc*azt\$$
(C127) $ev4az:ev4*azt\$$
(C128) $ev5az:ev5*azt\$$
(C129) $coe1:q4+rcazt\$$
(C130) $coe:q4-rcazt\$$
(C131) $a141:q4*d1q1\$$
(C132) $a441:ev4az*drcq1+coe1*d4q1\$$
(C133) $a541:-ev5az*drcq1+coe*d5q1\$$
(C134) $cp[4,1]:cg1*a141+cg2*a441+cg3*a541\$$
(C135) $a142:q4*d1q2\$$
(C136) $a442:ev4az*drcq2+coe1*d4q2\$$
(C137) $a542:-ev5az*drcq2+coe*d5q2\$$
(C138) $cp[4,2]:cg1*a142+cg2*a442+cg3*a542\$$
(C139) $a143:q4*d1q3\$$
(C140) $a443:ev4az*drcq3+coe1*d4q3\$$
(C141) $a543:-ev5az*drcq3+coe*d5q3\$$
(C142) $cp[4,3]:cg1*a143+cg2*a443+cg3*a543\$$
(C143) $a144:q4*d1q4+ev1\$$
(C144) $a444:ev4+ev4az*drcq4+coe1*d4q4\$$
(C145) $a544:ev5-ev5az*drcq4+coe*d5q4\$$
(C146) $cp[4,4]:cg1*a144+cg2*a444+cg3*a544\$$
(C147) $a145:q4*d1q5\$$
(C148) $a445:ev4az*drcq5+coe1*d4q5\$$
(C149) $a545:-ev5az*drcq5+coe*d5q5\$$
(C150) $cp[4,5]:cg1*a145+cg2*a445+cg3*a545\$$
(C151) $rctt:rc*tt\$$

(C152) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C153) rt:rc*dttq1+tt*drcq1\$
(C154) a151:2*coe*d1q1\$
(C155) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C156) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C157) cp[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C158) rt:rc*dttq2+tt*drcq2\$
(C159) a152:coe*d1q2-d1q1*q2\$
(C160) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C161) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C162) cp[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C163) rt:rc*dttq3+tt*drcq3\$
(C164) a153:coe*d1q3-d1q1*q3\$
(C165) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C166) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C167) cp[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C168) rt:rc*dttq4+tt*drcq4\$
(C169) a154:coe*d1q4-d1q1*q4\$
(C170) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C171) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C172) cp[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C173) rt:tt*drcq5\$
(C174) a155:coe*d1q5\$
(C175) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C176) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C177) cp[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C178) q1:q1\$
(C179) q2:q2\$
(C180) q3:q3\$
(C181) q4:-q4\$
(C182) q5:q5\$
(C183) ztx:-ztx\$
(C184) zty:-zty\$
(C185) sign:-1\$
(C186) cgg1:(gam-1)/gam\$
(C187) cgg2:1/(2*gam)\$
(C188) sada:sqrt(ztx**2+zty**2+ztz**2)\$
(C189) axt:ztx/sada\$
(C190) ayt:zty/sada\$
(C191) azt:ztz/sada\$
(C192) rqrq:q2**2+q3**2+q4**2\$
(C193) q6:1/q1\$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C195) prgam:pr*gam\$
(C196) pp:q5+pr\$
(C197) c:sqrt(prgam*q6)\$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C199) rc:q1*c\$
(C200) csad:c*sada\$
(C201) e1:tt*sada\$
(C202) e4:e1+csad\$

(C203) e5:e1-csad\$
(C204) ev1:e1\$
(C205) ev4:e1\$
(C206) ev5:e5\$
(C209) cg1:cgg1\$
(C208) cg2:cgg2\$
(C209) cg3:cgg2\$
(C210) d1q1:-ev1*q6\$
(C211) d1q2:ztx*q6\$
(C212) d1q3:zty*q6\$
(C213) d1q4:ztz*q6\$
(C214) d1q5:0.0\$
(C215) coe:gam*(gam-1)/(2*rc)\$
(C216) gm1q6:(gam-1)*q6\$
(C217) drcq1:coe*q5\$
(C218) drcq2:-coe*q2\$
(C219) drcq3:-coe*q3\$
(C220) drcq4:-coe*q4\$
(C221) drcq5:coe*q1\$
(C222) dcq1:(drcq1-c)*q6\$
(C223) dcq2:drcq2*q6\$
(C224) dcq3:drcq3*q6\$
(C225) dcq4:drcq4*q6\$
(C226) dcq5:drcq5*q6\$
(C227) depq1:0.5*gm1q6*rqrq*q6\$
(C228) depq2:-q2*gm1q6\$
(C229) depq3:-q3*gm1q6\$
(C230) depq4:-q4*gm1q6\$
(C231) depq5:gam\$
(C232) dttq1:-tt*q6\$
(C233) dttq2:axt*q6\$
(C234) dttq3:ayt*q6\$
(C235) dttq4:azt*q6\$
(C236) dttq5:0.0\$
(C237) d4q1:sada*(dttq1+dcq1)\$
(C238) d4q2:sada*(dttq2+dcq2)\$
(C239) d4q3:sada*(dttq3+dcq3)\$
(C240) d4q4:sada*(dttq4+dcq4)\$
(C241) d4q5:sada*dcq5\$
(C242) d5q1:sada*(dttq1-dcq1)\$
(C243) d5q2:sada*(dttq2-dcq2)\$
(C244) d5q3:sada*(dttq3-dcq3)\$
(C245) d5q4:sada*(dttq4-dcq4)\$
(C246) d5q5:-d4q5\$
(C247) a411:ev4+q1*d4q1\$
(C248) a511:ev5+q1*d5q1\$
(C249) cm[1,1]:cg2*a411+cg3*a511\$
(C250) cm[1,2]: (cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C251) cm[1,3]: (cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C252) cm[1,4]: (cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C253) cm[1,5]: (cg2*d4q5+cg3*d5q5)*q1\$

(C254) rcaxt:rc*axt\$
 (C255) ev4ax:ev4*axt\$
 (C256) ev5ax:ev5*axt\$
 (C257) coe1:q2+rcaxt\$
 (C258) coe:q2-rcaxt\$
 (C259) a121:q2*d1q1\$
 (C260) a421:ev4ax*drcq1+coe1*d4q1\$
 (C261) a521:-ev5ax*drcq1+coe*d5q1\$
 (C262) cm[2,1]:cg1*a121+cg2*a421+cg3*a521\$
 (C263) a122:q2*d1q2+ev1\$
 (C264) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
 (C265) a522:ev5-ev5ax*drcq2+coe*d5q2\$
 (C266) cm[2,2]:cg1*a122+cg2*a422+cg3*a522\$
 (C267) a123:q2*d1q3\$
 (C268) a423:ev4ax*drcq3+coe1*d4q3\$
 (C269) a523:-ev5ax*drcq3+coe*d5q3\$
 (C270) cm[2,3]:cg1*a123+cg2*a423+cg3*a523\$
 (C271) a124:q2*d1q4\$
 (C272) a424:ev4ax*drcq4+coe1*d4q4\$
 (C273) a524:-ev5ax*drcq4+coe*d5q4\$
 (C274) cm[2,4]:cg1*a124+cg2*a424+cg3*a524\$
 (C275) a125:q2*d1q5\$
 (C276) a425:ev4ax*drcq5+coe1*d4q5\$
 (C277) a525:-ev5ax*drcq5+coe*d5q5\$
 (C278) cm[2,5]:cg1*a125+cg2*a425+cg3*a525\$
 (C279) rcayt:rc*ayt\$
 (C280) ev4ay:ev4*ayt\$
 (C281) ev5ay:ev5*ayt\$
 (C282) coe1:q3+rcayt\$
 (C283) coe:q3-rcayt\$
 (C284) a131:q3*d1q1\$
 (C285) a431:ev4ay*drcq1+coe1*d4q1\$
 (C286) a531:-ev5ay*drcq1+coe*d5q1\$
 (C287) cm[3,1]:cg1*a131+cg2*a431+cg3*a531\$
 (C288) a132:q3*d1q2\$
 (C289) a432:ev4ay*drcq2+coe1*d4q2\$
 (C290) a532:-ev5ay*drcq2+coe*d5q2\$
 (C291) cm[3,2]:cg1*a132+cg2*a432+cg3*a532\$
 (C292) a133:q3*d1q3+ev1\$
 (C293) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
 (C294) a533:ev5-ev5ay*drcq3+coe*d5q3\$
 (C295) cm[3,3]:cg1*a133+cg2*a433+cg3*a533\$
 (C296) a134:q3*d1q4\$
 (C297) a434:ev4ay*drcq4+coe1*d4q4\$
 (C298) a534:-ev5ay*drcq4+coe*d5q4\$
 (C299) cm[3,4]:cg1*a134+cg2*a434+cg3*a534\$
 (C300) a135:q3*d1q5\$
 (C301) a435:ev4ay*drcq5+coe1*d4q5\$
 (C302) a535:-ev5ay*drcq5+coe*d5q5\$
 (C303) cm[3,5]:cg1*a135+cg2*a435+cg3*a535\$
 (C304) rcazt:rc*azt\$

(C305) ev4az:ev4*azt\$
(C306) ev5az:ev5*azt\$
(C307) coe1:q4+rcazt\$
(C308) coe:q4-rcazt\$
(C309) a141:q4*d1q1\$
(C310) a441:ev4az*drcq1+coe1*d4q1\$
(C311) a541:-ev5az*drcq1+coe*d5q1\$
(C312) cm[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C313) a142:q4*d1q2\$
(C314) a442:ev4az*drcq2+coe1*d4q2\$
(C315) a542:-ev5az*drcq2+coe*d5q2\$
(C316) cm[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C317) a143:q4*d1q3\$
(C318) a443:ev4az*drcq3+coe1*d4q3\$
(C319) a543:-ev5az*drcq3+coe*d5q3\$
(C320) cm[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C321) a144:q4*d1q4+ev1\$
(C322) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C323) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C324) cm[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C325) a145:q4*d1q5\$
(C326) a445:ev4az*drcq5+coe1*d4q5\$
(C327) a545:-ev5az*drcq5+coe*d5q5\$
(C328) cm[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C329) rctt:rc*tt\$
(C330) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C331) rt:rc*dttq1+tt*drcq1\$
(C332) a151:2*coe*d1q1\$
(C333) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C334) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C335) cm[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C336) rt:rc*dttq2+tt*drcq2\$
(C337) a152:coe*d1q2-d1q1*q2\$
(C338) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C339) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C340) cm[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C341) rt:rc*dttq3+tt*drcq3\$
(C342) a153:coe*d1q3-d1q1*q3\$
(C343) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C344) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C346) rt:rc*dttq4+tt*drcq4\$
(C347) a154:coe*d1q4-d1q1*q4\$
(C348) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C349) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C350) cm[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C351) rt:tt*drcq5\$
(C352) a155:coe*d1q5\$
(C353) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C354) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C355) cm[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C356) diff:cp.m+m.cm\$

CCSUP1

(C357) diff:ratexpand(diff);
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
(D357)
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
[[0 0 0 0 0]]
(C358) closefile(Ccsup1)\$

```

(C3) cp:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C4) cm:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C5) diff:matrix([0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,
0,0,0,0])$
(C6) m:matrix([1,0,0,0,0],[0,1,0,0,0],[0,0,1,0,0],[0,0,0,-1,0],[0,
0,0,1])$
(C7) sign:1$
(C8) cg1:(gam-1)/gam$
(C9) cg2:1/(2*gam)$
(C10) sada:sqrt(ztx**2+zty**2+ztz**2)$
(C11) axt:ztx/sada$
(C12) ayt:zty/sada$
(C13) azt:ztz/sada$
(C14) rqrq:q2**2+q3**2+q4**2$
(C15) q6:1/q1$
(C16) pr:(gam-1)*(q5-0.5*rqrq*q6)$
(C17) prgam:pr*gam$
(C18) pp:q5+pr$
(C19) c:sqrt(prgam*q6)$
(C20) tt:(q2*axt+q3*ayt+q4*azt)*q6$
(C21) rc:q1*c$
(C22) csad:c*sada$
(C23) e1:tt*sada$
(C24) e4:e1+csad$
(C25) e5:e1-csad$
(C26) ev1:e1$
(C27) ev4:e4$
(C28) ev5:0.0$
(C29) cg1:cgg1$
(C30) cg2:cgg2$
(C31) cg3:0.0$
(C32) d1q1:-ev1*q6$
(C33) d1q2:ztx*q6$
(C34) d1q3:zty*q6$
(C35) d1q4:ztz*q6$
(C36) d1q5:0.0$
(C37) coe:gam*(gam-1)/(2*rc)$
(C38) gmlq6:(gam-1)*q6$
(C39) drcq1:coe*q5$
(C40) drcq2:-coe*q2$
(C41) drcq3:-coe*q3$
(C42) drcq4:-coe*q4$
(C43) drcq5:coe*q1$
(C44) dcq1:(drcq1-c)*q6$
(C45) dcq2:drcq2*q6$
(C46) dcq3:drcq3*q6$
(C47) dcq4:drcq4*q6$
(C48) dcq5:drcq5*q6$
(C49) depq1:0.5*gmlq6*rqrq*q6$

```

(C50) depq2:-q2*gm1q6\$
(C51) depq3:-q3*gm1q6\$
(C52) depq4:-q4*gm1q6\$
(C53) depq5:gam\$
(C54) dttq1:-tt*q6\$
(C55) dttq2:axt*q6\$
(C56) dttq3:ayt*q6\$
(C57) dttq4:azt*q6\$
(C58) dttq5:0.0\$
(C59) d4q1:sada*(dttq1+dcq1)\$
(C60) d4q2:sada*(dttq2+dcq2)\$
(C61) d4q3:sada*(dttq3+dcq3)\$
(C62) d4q4:sada*(dttq4+dcq4)\$
(C63) d4q5:sada*dcq5\$
(C64) d5q1:sada*(dttq1-dcq1)\$
(C65) d5q2:sada*(dttq2-dcq2)\$
(C66) d5q3:sada*(dttq3-dcq3)\$
(C67) d5q4:sada*(dttq4-dcq4)\$
(C68) d5q5:-d4q5\$
(C69) a411:ev4+q1*d4q1\$
(C70) a511:ev5+q1*d5q1\$
(C71) cp[1,1]:cg2*a411+cg3*a511\$
(C72) cp[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C73) cp[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C74) cp[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C75) cp[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$
(C76) rcaxt:rc*axt\$
(C77) ev4ax:ev4*axt\$
(C78) ev5ax:ev5*axt\$
(C79) coe1:q2+rcaxt\$
(C80) coe:q2-rcaxt\$
(C81) a121:q2*d1q1\$
(C82) a421:ev4ax*drcq1+coe1*d4q1\$
(C83) a521:-ev5ax*drcq1+coe*d5q1\$
(C84) cp[2,1]:cg1*a121+cg2*a421+cg3*a521\$
(C85) a122:q2*d1q2+ev1\$
(C86) a422:ev4+ev4ax*drcq2+coe1*d4q2\$
(C87) a522:ev5-ev5ax*drcq2+coe*d5q2\$
(C88) cp[2,2]:cg1*a122+cg2*a422+cg3*a522\$
(C89) a123:q2*d1q3\$
(C90) a423:ev4ax*drcq3+coe1*d4q3\$
(C91) a523:-ev5ax*drcq3+coe*d5q3\$
(C92) cp[2,3]:cg1*a123+cg2*a423+cg3*a523\$
(C93) a124:q2*d1q4\$
(C94) a424:ev4ax*drcq4+coe1*d4q4\$
(C95) a524:-ev5ax*drcq4+coe*d5q4\$
(C96) cp[2,4]:cg1*a124+cg2*a424+cg3*a524\$
(C97) a125:q2*d1q5\$
(C98) a425:ev4ax*drcq5+coe1*d4q5\$
(C99) a525:-ev5ax*drcq5+coe*d5q5\$
(C100) cp[2,5]:cg1*a125+cg2*a425+cg3*a525\$

(C101) rcayt:rc*ayt\$
(C102) ev4ay:ev4*ayt\$
(C103) ev5ay:ev5*ayt\$
(C104) coe1:q3+rcayt\$
(C105) coe:q3-rcayt\$
(C106) a131:q3*d1q1\$
(C107) a431:ev4ay*drcq1+coe1*d4q1\$
(C108) a531:-ev5ay*drcq1+coe*d5q1\$
(C109) cp[3,1]:cg1*a131+cg2*a431+cg3*a531\$
(C110) a132:q3*d1q2\$
(C111) a432:ev4ay*drcq2+coe1*d4q2\$
(C112) a532:-ev5ay*drcq2+coe*d5q2\$
(C113) cp[3,2]:cg1*a132+cg2*a432+cg3*a532\$
(C114) a133:q3*d1q3+ev1\$
(C115) a433:ev4+ev4ay*drcq3+coe1*d4q3\$
(C116) a533:ev5-ev5ay*drcq3+coe*d5q3\$
(C117) cp[3,3]:cg1*a133+cg2*a433+cg3*a533\$
(C118) a134:q3*d1q4\$
(C119) a434:ev4ay*drcq4+coe1*d4q4\$
(C120) a534:-ev5ay*drcq4+coe*d5q4\$
(C121) cp[3,4]:cg1*a134+cg2*a434+cg3*a534\$
(C122) a135:q3*d1q5\$
(C123) a435:ev4ay*drcq5+coe1*d4q5\$
(C124) a535:-ev5ay*drcq5+coe*d5q5\$
(C125) cp[3,5]:cg1*a135+cg2*a435+cg3*a535\$
(C126) rcazt:rc*azt\$
(C127) ev4az:ev4*azt\$
(C128) ev5az:ev5*azt\$
(C129) coe1:q4+rcazt\$
(C130) coe:q4-rcazt\$
(C131) a141:q4*d1q1\$
(C132) a441:ev4az*drcq1+coe1*d4q1\$
(C133) a541:-ev5az*drcq1+coe*d5q1\$
(C134) cp[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C135) a142:q4*d1q2\$
(C136) a442:ev4az*drcq2+coe1*d4q2\$
(C137) a542:-ev5az*drcq2+coe*d5q2\$
(C138) cp[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C139) a143:q4*d1q3\$
(C140) a443:ev4az*drcq3+coe1*d4q3\$
(C141) a543:-ev5az*drcq3+coe*d5q3\$
(C142) cp[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C143) a144:q4*d1q4+ev1\$
(C144) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C145) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C146) cp[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C147) a145:q4*d1q5\$
(C148) a445:ev4az*drcq5+coe1*d4q5\$
(C149) a545:-ev5az*drcq5+coe*d5q5\$
(C150) cp[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C151) rctt:rc*tt\$

(C152) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C153) rt:rc*dttq1+tt*drcq1\$
(C154) a151:2*coe*d1q1\$
(C155) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C156) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C157) cp[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C158) rt:rc*dttq2+tt*drcq2\$
(C159) a152:coe*d1q2-d1q1*q2\$
(C160) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C161) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C162) cp[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C163) rt:rc*dttq3+tt*drcq3\$
(C164) a153:coe*d1q3-d1q1*q3\$
(C165) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C166) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C167) cp[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C168) rt:rc*dttq4+tt*drcq4\$
(C169) a154:coe*d1q4-d1q1*q4\$
(C170) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C171) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C172) cp[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C173) rt:tt*drcq5\$
(C174) a155:coe*d1q5\$
(C175) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C176) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C177) cp[5,5]:cg1*a155+cg2*a455+cg3*a555\$
(C178) q1:q1\$
(C179) q2:q2\$
(C180) q3:q3\$
(C181) q4:-q4\$
(C182) q5:q5\$
(C183) ztx:-ztx\$
(C184) zty:-zty\$
(C185) sign:-1\$
(C186) cgg1:(gam-1)/gam\$
(C187) cgg2:1/(2*gam)\$
(C188) sada:sqrt(ztx**2+zty**2+ztz**2)\$
(C189) axt:ztx/sada\$
(C190) ayt:zty/sada\$
(C191) azt:ztz/sada\$
(C192) rqrq:q2**2+q3**2+q4**2\$
(C193) q6:1/q1\$
(C194) pr:(gam-1)*(q5-0.5*rqrq*q6)\$
(C195) prgam:pr*gam\$
(C196) pp:q5+pr\$
(C197) c:sqrt(prgam*q6)\$
(C198) tt:(q2*axt+q3*ayt+q4*azt)*q6\$
(C199) rc:q1*c\$
(C200) csad:c*sada\$
(C201) e1:tt*sada\$
(C202) e4:e1+csad\$

(C203) e5:e1-csad\$
(C204) ev1:e1\$
(C205) ev4:0.0\$
(C206) ev5:e5\$
(C207) cg1:cgg1\$
(C208) cg2:0.0\$
(C209) cg3:cgg2\$
(C210) d1q1:-ev1*q6\$
(C211) d1q2:ztx*q6\$
(C212) d1q3:zty*q6\$
(C213) d1q4:ztz*q6\$
(C214) d1q5:0.0\$
(C215) coe:gam*(gam-1)/(2*rc)\$
(C216) gm1q6:(gam-1)*q6\$
(C217) drcq1:coe*q5\$
(C218) drcq2:-coe*q2\$
(C219) drcq3:-coe*q3\$
(C220) drcq4:-coe*q4\$
(C221) drcq5:coe*q1\$
(C222) dcq1:(drcq1-c)*q6\$
(C223) dcq2:drcq2*q6\$
(C224) dcq3:drcq3*q6\$
(C225) dcq4:drcq4*q6\$
(C226) dcq5:drcq5*q6\$
(C227) depq1:0.5*gm1q6*rqrq*q6\$
(C228) depq2:-q2*gm1q6\$
(C229) depq3:-q3*gm1q6\$
(C230) depq4:-q4*gm1q6\$
(C231) depq5:gam\$
(C232) dttq1:-tt*q6\$
(C233) dttq2:axt*q6\$
(C234) dttq3:ayt*q6\$
(C235) dttq4:azt*q6\$
(C236) dttq5:0.0\$
(C237) d4q1:sada*(dttq1+dcq1)\$
(C238) d4q2:sada*(dttq2+dcq2)\$
(C239) d4q3:sada*(dttq3+dcq3)\$
(C240) d4q4:sada*(dttq4+dcq4)\$
(C241) d4q5:sada*dcq5\$
(C242) d5q1:sada*(dttq1-dcq1)\$
(C243) d5q2:sada*(dttq2-dcq2)\$
(C244) d5q3:sada*(dttq3-dcq3)\$
(C245) d5q4:sada*(dttq4-dcq4)\$
(C246) d5q5:-d4q5\$
(C247) a411:ev4+q1*d4q1\$
(C248) a511:ev5+q1*d5q1\$
(C249) cm[1,1]:cg2*a411+cg3*a511\$
(C250) cm[1,2]:(cg1*d1q2+cg2*d4q2+cg3*d5q2)*q1\$
(C251) cm[1,3]:(cg1*d1q3+cg2*d4q3+cg3*d5q3)*q1\$
(C252) cm[1,4]:(cg1*d1q4+cg2*d4q4+cg3*d5q4)*q1\$
(C253) cm[1,5]:(cg2*d4q5+cg3*d5q5)*q1\$

(C254) $rcaxt:rc*axt\$$
(C255) $ev4ax:ev4*axt\$$
(C256) $ev5ax:ev5*axt\$$
(C257) $coe1:q2+rcaxt\$$
(C258) $coe:q2-rcaxt\$$
(C259) $a121:q2*d1q1\$$
(C260) $a421:ev4ax*drcq1+coe1*d4q1\$$
(C261) $a521:-ev5ax*drcq1+coe*d5q1\$$
(C262) $cm[2,1]:cg1*a121+cg2*a421+cg3*a521\$$
(C263) $a122:q2*d1q2+ev1\$$
(C264) $a422:ev4+ev4ax*drcq2+coe1*d4q2\$$
(C265) $a522:ev5-ev5ax*drcq2+coe*d5q2\$$
(C266) $cm[2,2]:cg1*a122+cg2*a422+cg3*a522\$$
(C267) $a123:q2*d1q3\$$
(C268) $a423:ev4ax*drcq3+coe1*d4q3\$$
(C269) $a523:-ev5ax*drcq3+coe*d5q3\$$
(C270) $cm[2,3]:cg1*a123+cg2*a423+cg3*a523\$$
(C271) $a124:q2*d1q4\$$
(C272) $a424:ev4ax*drcq4+coe1*d4q4\$$
(C273) $a524:-ev5ax*drcq4+coe*d5q4\$$
(C274) $cm[2,4]:cg1*a124+cg2*a424+cg3*a524\$$
(C275) $a125:q2*d1q5\$$
(C276) $a425:ev4ax*drcq5+coe1*d4q5\$$
(C277) $a525:-ev5ax*drcq5+coe*d5q5\$$
(C278) $cm[2,5]:cg1*a125+cg2*a425+cg3*a525\$$
(C279) $rcayt:rc*ayt\$$
(C280) $ev4ay:ev4*ayt\$$
(C281) $ev5ay:ev5*ayt\$$
(C282) $coe1:q3+rcayt\$$
(C283) $coe:q3-rcayt\$$
(C284) $a131:q3*d1q1\$$
(C285) $a431:ev4ay*drcq1+coe1*d4q1\$$
(C286) $a531:-ev5ay*drcq1+coe*d5q1\$$
(C287) $cm[3,1]:cg1*a131+cg2*a431+cg3*a531\$$
(C288) $a132:q3*d1q2\$$
(C289) $a432:ev4ay*drcq2+coe1*d4q2\$$
(C290) $a532:-ev5ay*drcq2+coe*d5q2\$$
(C291) $cm[3,2]:cg1*a132+cg2*a432+cg3*a532\$$
(C292) $a133:q3*d1q3+ev1\$$
(C293) $a433:ev4+ev4ay*drcq3+coe1*d4q3\$$
(C294) $a533:ev5-ev5ay*drcq3+coe*d5q3\$$
(C295) $cm[3,3]:cg1*a133+cg2*a433+cg3*a533\$$
(C296) $a134:q3*d1q4\$$
(C297) $a434:ev4ay*drcq4+coe1*d4q4\$$
(C298) $a534:-ev5ay*drcq4+coe*d5q4\$$
(C299) $cm[3,4]:cg1*a134+cg2*a434+cg3*a534\$$
(C300) $a135:q3*d1q5\$$
(C301) $a435:ev4ay*drcq5+coe1*d4q5\$$
(C302) $a535:-ev5ay*drcq5+coe*d5q5\$$
(C303) $cm[3,5]:cg1*a135+cg2*a435+cg3*a535\$$
(C304) $rcazt:rc*azt\$$

(C305) ev4az:ev4*azt\$
(C306) ev5az:ev5*azt\$
(C307) coe1:q4+rcazt\$
(C308) coe:q4-rcazt\$
(C309) a141:q4*d1q1\$
(C310) a441:ev4az*drcq1+coe1*d4q1\$
(C311) a541:-ev5az*drcq1+coe*d5q1\$
(C312) cm[4,1]:cg1*a141+cg2*a441+cg3*a541\$
(C313) a142:q4*d1q2\$
(C314) a442:ev4az*drcq2+coe1*d4q2\$
(C315) a542:-ev5az*drcq2+coe*d5q2\$
(C316) cm[4,2]:cg1*a142+cg2*a442+cg3*a542\$
(C317) a143:q4*d1q3\$
(C318) a443:ev4az*drcq3+coe1*d4q3\$
(C319) a543:-ev5az*drcq3+coe*d5q3\$
(C320) cm[4,3]:cg1*a143+cg2*a443+cg3*a543\$
(C321) a144:q4*d1q4+ev1\$
(C322) a444:ev4+ev4az*drcq4+coe1*d4q4\$
(C323) a544:ev5-ev5az*drcq4+coe*d5q4\$
(C324) cm[4,4]:cg1*a144+cg2*a444+cg3*a544\$
(C325) a145:q4*d1q5\$
(C326) a445:ev4az*drcq5+coe1*d4q5\$
(C327) a545:-ev5az*drcq5+coe*d5q5\$
(C328) cm[4,5]:cg1*a145+cg2*a445+cg3*a545\$
(C329) rctt:rc*tt\$
(C330) coe:0.5*(q2**2+q3**2+q4**2)*q6\$
(C331) rt:rc*dttq1+tt*drcq1\$
(C332) a151:2*coe*d1q1\$
(C333) a451:ev4*(depq1+rt)+(pp+rctt)*d4q1\$
(C334) a551:ev5*(depq1-rt)+(pp-rctt)*d5q1\$
(C335) cm[5,1]:cg1*a151+cg2*a451+cg3*a551\$
(C336) rt:rc*dttq2+tt*drcq2\$
(C337) a152:coe*d1q2-d1q1*q2\$
(C338) a452:ev4*(depq2+rt)+(pp+rctt)*d4q2\$
(C339) a552:ev5*(depq2-rt)+(pp-rctt)*d5q2\$
(C340) cm[5,2]:cg1*a152+cg2*a452+cg3*a552\$
(C341) rt:rc*dttq3+tt*drcq3\$
(C342) a153:coe*d1q3-d1q1*q3\$
(C343) a453:ev4*(depq3+rt)+(pp+rctt)*d4q3\$
(C344) a553:ev5*(depq3-rt)+(pp-rctt)*d5q3\$
(C345) cm[5,3]:cg1*a153+cg2*a453+cg3*a553\$
(C346) rt:rc*dttq4+tt*drcq4\$
(C347) a154:coe*d1q4-d1q1*q4\$
(C348) a454:ev4*(depq4+rt)+(pp+rctt)*d4q4\$
(C349) a554:ev5*(depq4-rt)+(pp-rctt)*d5q4\$
(C350) cm[5,4]:cg1*a154+cg2*a454+cg3*a554\$
(C351) rt:tt*drcq5\$
(C352) a155:coe*d1q5\$
(C353) a455:ev4*(depq5+rt)+(pp+rctt)*d4q5\$
(C354) a555:ev5*(depq5-rt)+(pp-rctt)*d5q5\$
(C355) cm[5,5]:cg1*a155+cg2*a455+cg3*a555\$

CCSUB1

(C356) diff:cp.m+m.cm\$
(C357) diff:ratexpand(diff);
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
(D357)
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
[0 0 0 0 0]
(C358) closefile(Ccsub1)\$
■